

# Hydraulic Tools and Equipment

## Introduction

Hydraulic tools are an important part of a rescue squad's inventory. They are the backbone of most vehicle extrications and offer an excellent option for heavy lifting operations. As a driver/operator, it is important to understand all aspects of hydraulic tools including not only the tool itself, but their source of power, associated accessories and even the science behind their operation.

## Theory

### Fluid Mechanics

Hydraulics is the branch of science that deals with the practical applications (as transmission of energy or effects of flow) of liquid in motion. A large part of the theoretical foundation for hydraulics is derived from fluid mechanics, which is the study of the effects of forces and energy on liquids and gases. The term "fluid" is often used interchangeably with the term "liquid". However, a liquid is actually a type of fluid. Fluids are defined as substances that have a tendency to freely flow or conform to the shape of their container. Both liquids and gases meet this criteria and are considered fluids. Therefore hydraulics is the equivalent of pneumatics when dealing with liquids instead of gases.

All fluids are compressible to some extent (changes in pressure and/or temperature will result in changes in their density). However, in most applications the pressure/temperature changes are so small that any changes in density are negligible. Therefore, fluids are often grouped into two categories:

- **Compressible** – a fluid whose density significantly changes with changes in pressure; the volume of a compressible fluid decreases as the pressure exerted on the fluid increases; gases are often considered compressible fluids
- **Incompressible** – a fluid whose density does not significantly change with pressure; the volume of an incompressible fluid will not change as the pressure exerted on the fluid increases; liquids are often considered incompressible fluids

### Pressure

Before proceeding further, it is important to review the definition of pressure. Pressure is force per unit area applied in a direction perpendicular to the surface of an object.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

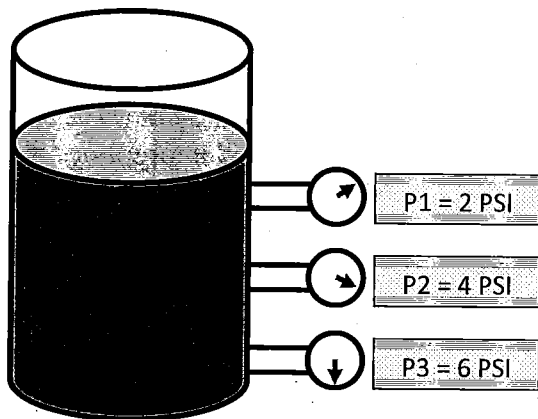
## Pressure (continued)

The SI unit of pressure is the pascal ( $\text{Pa} = \text{N/m}^2$ ). The U.S. customary system unit of pressure is pounds per square inch ( $\text{psi} = \text{lbs/in}^2$ ). As the equation on the previous page shows, pressure is affected by changes in the force being applied or the area in which the force is applied.

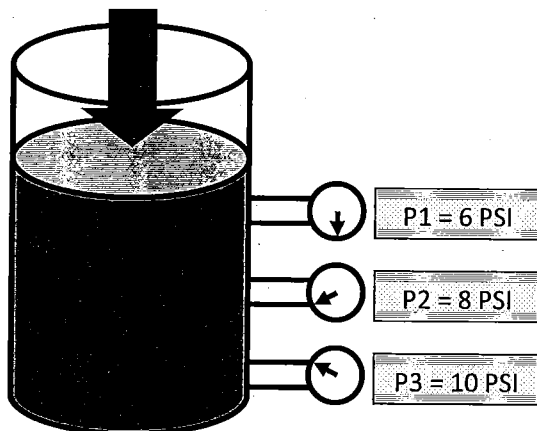
## Pascal's Law

One important principle relating to fluid mechanics is Pascal's Law. The law states that any change in pressure at any point in a confined fluid will result in an equal change in pressure (without loss) throughout the rest of the fluid and to the walls of the container.

### Example 1:



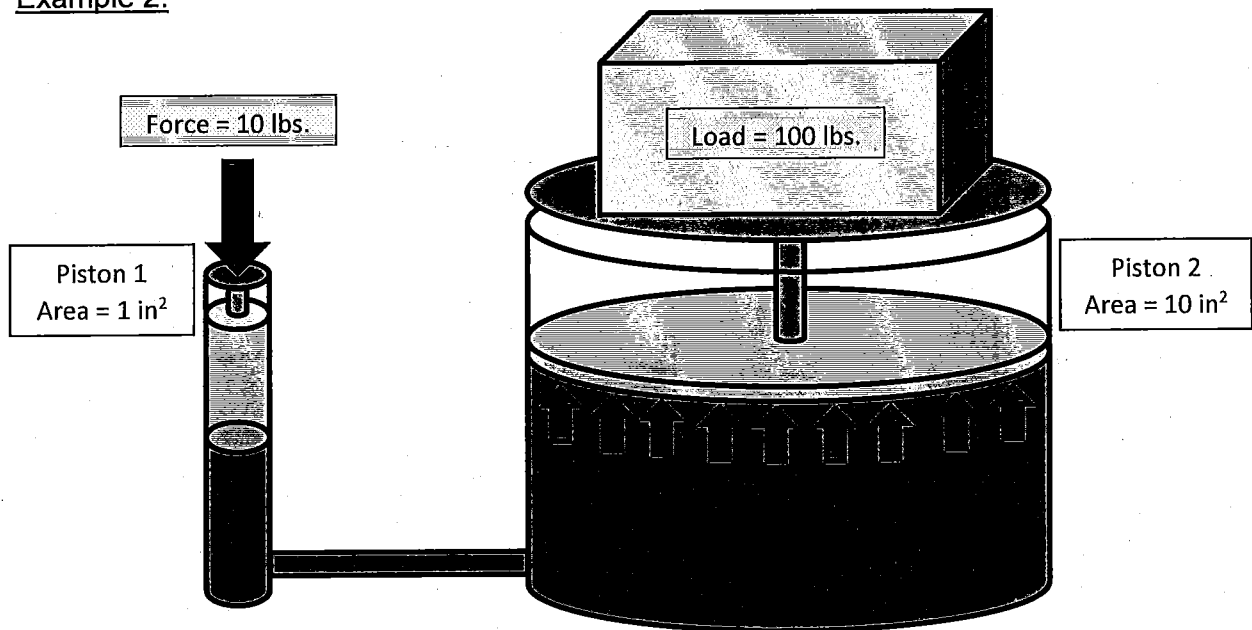
The container on the left contains a fluid. Three pressure gauges are connected to the container at different depths. As the depth of the fluid increases, the pressure increases due to the mass above it.



An additional pressure of 4 psi is applied to the fluid. As a result, the pressure will increase throughout the fluid. According to Pascal's Law, the pressure increase throughout all parts of the container will be equal. Therefore, each pressure gauge will increase by 4 psi.

The above example illustrates Pascal's Law at a basic level. The next example will demonstrate Pascal's Law in a slightly more complex system. This example will show how forces can be multiplied in hydraulic systems, providing the basis for the design of hydraulic rescue tools.

Example 2:



Example 2 demonstrates how a hydraulic lift operates at a basic level. A force is applied to the piston on the left. This force causes an increase in pressure on the hydraulic system, which is transmitted to the cylinder on the right. The pressure acts on the piston on the right, which transmits force to lift the block. One very important aspect of the system shown above is that only 10 lbs. on input force is required to lift the 100 lb. block. How can this be? The answer can be drawn from Example 1 and the application of Pascal's Law:

Remember, **Pressure (P) = Force (F) / Area (A)**

So from the diagram, the pressure in the cylinder on the left is:

$$\begin{aligned}\text{Pressure} &= \text{Force on Piston 1} / \text{Area of Piston 1} \\ \text{Pressure} &= 10 \text{ lbs} / 1 \text{ in}^2 = 10 \text{ lbs/in}^2 = 10 \text{ psi}\end{aligned}$$

Pascal's Law states that the pressure in the entire system must be equal. Therefore, if there is 10 psi in the cylinder on the left, there will be 10 psi in the cylinder on the right.

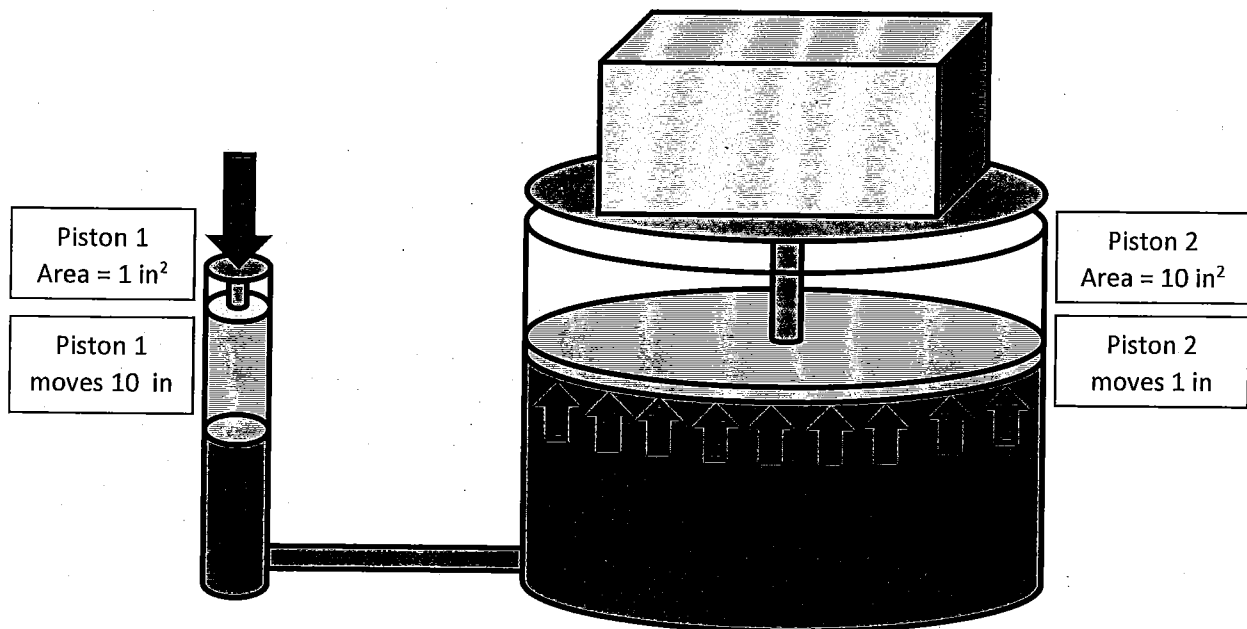
For the cylinder on the right, the pressure is known. Rearranging the equation yields:

**Force (F) = Pressure (P) x Area (A)**

$$\begin{aligned}\text{Force on Piston 2} &= (\text{Pressure}) \times (\text{Area of Piston 2}) \\ \text{Force on Piston 2} &= (10 \text{ lbs/in}^2) \times (10 \text{ in}^2) = 100 \text{ lbs}\end{aligned}$$

As this example shows, the input force is increased (multiplied) by a factor of 10 because the area of Piston 2 is 10x that of Piston 1.

Another noteworthy point from Example 2 is the fact that Piston 1 moves farther than Piston 2:



The input force was multiplied by a factor of 10 but the resulting movement of the load was reduced by the same factor of 10. It is often said that, "nothing in life is free". Fluid mechanics is no different. The size and shape of the cylinders does not change. Therefore, since the pressure of the liquid remains the same, the volume must remain constant as well.

The volume of liquid in the cylinder can be expressed as:

$$\text{Volume (V)} = \text{Area of the Piston (A)} \times \text{Distance the Piston Moves (D)}$$

Therefore, for the cylinder on the left:

$$\begin{aligned} \text{Volume} &= (\text{Area of Piston 1}) \times (\text{Distance Piston 1 Moves}) \\ \text{Volume} &= (1 \text{ in}^2) \times (10 \text{ in}) = 10 \text{ in}^3 \end{aligned}$$

If  $10 \text{ in}^3$  of liquid is displaced in the cylinder on the left,  $10 \text{ in}^3$  of liquid must move to the cylinder on the right. Since the volume is known, the equation can be rearranged:

$$\text{Distance the Piston Moves (D)} = \text{Volume (V)} / \text{Area of the Piston (A)}$$

For the cylinder on the right:

$$\begin{aligned} \text{Distance Piston 2 Moves} &= \text{Volume} / \text{Area of Piston 2} \\ \text{Distance Piston 2 Moves} &= 10 \text{ in}^3 / 10 \text{ in}^2 = 1 \text{ in} \end{aligned}$$

Therefore, the tradeoff to gain increased output force is a decrease in lifting height.

## Hydraulic System Components

At a basic level, most hydraulic systems are made up of the following components:

- Fluid
- Reservoir
- Pump
- Actuator
- Valves

All of these components can be of different designs and complexities depending on the hydraulic systems application.

### Fluid

Hydraulic fluid (or more accurately, "liquid") is the medium for carrying the pressure through a hydraulic system that is translated into mechanical force and movement. There is a large variety of options for hydraulic fluid, each with specific characteristics to match specific applications. Some of the basic features of an "ideal" hydraulic fluid include:

- Thermal stability
- Hydrolytic stability (the ability to resist chemical decomposition in the presence of water)
- Low chemical corrosiveness
- High anti-wear characteristics
- Long life
- Low cost

To meet these demands, oil-based hydraulic fluids are often utilized. These fluids can be engineered to provide the desired viscosity, anti-wear and anti-corrosion properties with few operating, safety or maintenance problems.



However, there are certain applications where oil-based fluids should be avoided. Fire/rescue operations are examples of such situations. Hydraulic fluid exposure to high heat and/or flame could potentially result in a significant fire hazard. For this reason, most fire/rescue-specific hydraulic fluids fall into the category of fire-resistant hydraulic fluids (FRHFs).

The increased demand for fire-resistant hydraulic fluids came about from tragic incidents involving hydraulic fluid fires in industries such as steel mills, foundries and coal mines. Research was aimed at finding suitable replacements for oil-based fluids that could provide comparable hydraulic system performance without a significant increase in cost.

#### Water-Containing Fire-Resistant Fluids:

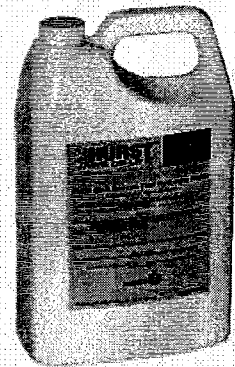
One solution to the problem of fire resistance is water. The introduction of water into hydraulic fluid provides an extinguishing agent should the fluid be exposed to flame. Water glycol and invert emulsions are the two major types of water-containing FRHFs:

- Water glycol – a solution of glycol (e.g. ethylene glycol) in water
  - Contains a variety of additives to provide viscosity, anti-wear and corrosion protection properties as well as a polymeric thickener
  - Approximately 40% water content
  - One of the dominant FRHFs on the market
  - Presents some environmental concerns
- Invert emulsion – a stable emulsion of water in oil
  - Also contains approximately 40% water
  - The outer phase of oil represents the wetting surface and provides the desired characteristics of oil-based hydraulic fluids
  - The inner phase of water acts as the fire-retardant
  - Contains oil-soluble additives to provide corrosion protection and reduce wear as well as emulsion stability

#### Synthetic Fire-Resistant Fluids:

The other approach to providing fire resistance was to engineer non-aqueous fluids with chemical properties that either resisted burning or generated products of combustion that would help extinguish any flames. The intent of these fluids was to eliminate the use of water, therefore eliminating the undesirable corrosive and wear characteristics.

- Phosphate Esters – the product of a reaction between phosphoric acid and aromatic ring-structure alcohols
  - Extremely fire resistant
  - Provide excellent wear resistance
- Polyol Esters – synthetic hydrocarbon, the product of a reaction between long-chain fatty acids (derived from animal and vegetable fats) and synthesized organic alcohols
  - Good fire resistance
  - Contain additives to provide anti-wear properties, corrosion protection and viscosity modification
  - Biodegradable



## Reservoir

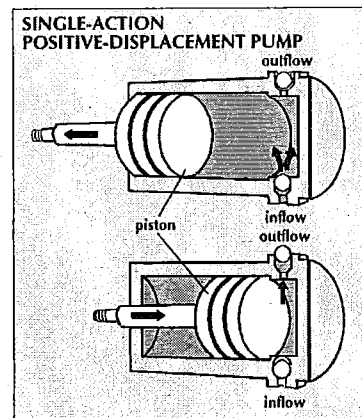
The reservoir is simply the storage tank for hydraulic fluid. Reservoirs come in different shapes and sizes depending upon the application. They are designed to provide sufficient fluid capacity for the rated number of operating tools while also maintaining a reserve. In addition, the reservoir must be large enough to hold the hydraulic systems fluid volume when the tools are not in use. In many cases, the reservoir is mounted in close proximity to the hydraulic pump.

## Pump

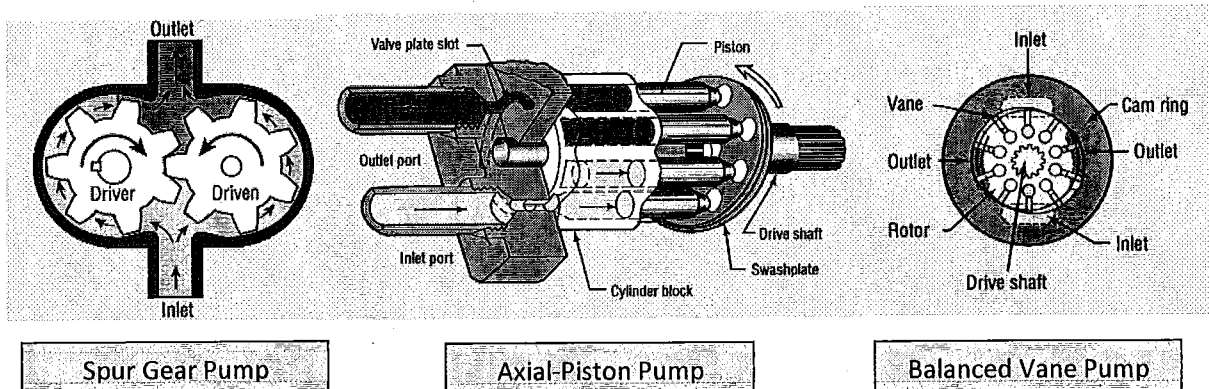
The hydraulic pump is the device that produces liquid movement or flow. (It is important to note that pumps do NOT generate pressure. In liquids, pressure is a function of resistance to flow. A pump's job is to generate that flow.)

As a review from a "Pumps and Hydraulics" class, pumps are classified as either positive-displacement or non-positive displacement. Most pumps used in hydraulic systems are positive displacement. Positive displacement pumps displace (or move) the same amount of liquid for each cycle of the pumping element. The precise and consistent liquid delivery is possible due to tight tolerances between the pumping element and pump housing.

Positive displacement pumps include reciprocating- and rotary-type. Reciprocating pumps are some of the most basic types of positive-displacement pumps. They contain an inlet and outlet and cylinder and piston.



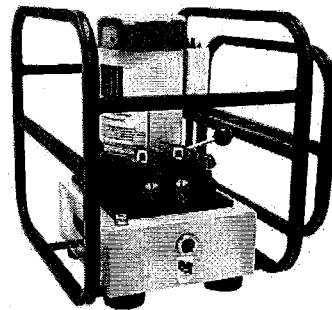
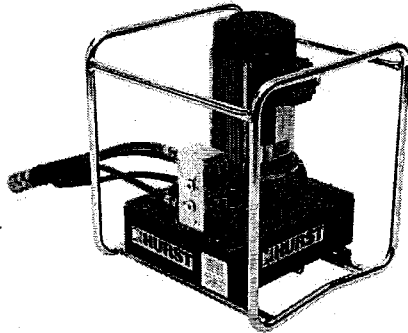
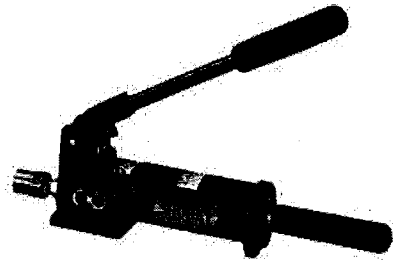
Rotary pumps include gear pumps (both external and internal), vane pumps and piston pumps.



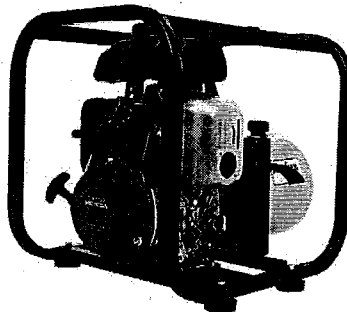
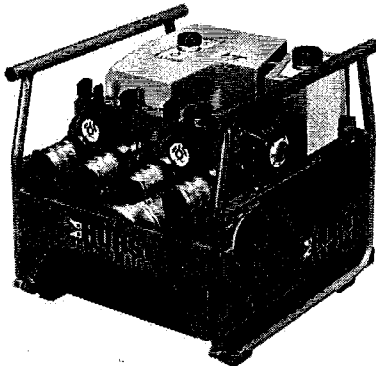
## Power Sources

Hydraulic pumps can be powered several different ways:

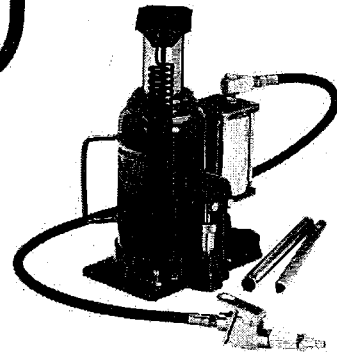
- Manually-operated – for use with single-action reciprocating positive displacement pumps
- Electric motor – can be DC or AC operated; common power source for many apparatus-mounted hydraulic pumps



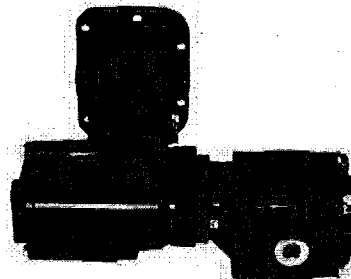
- Internal combustion engine – provides portability options; common type is a 4-stroke gasoline small engine



- Air pressure – compressed air powers the pump
- Power Take-Off (PTO) driven – PTOs can be mounted to the truck transmission and engaged via a switch in the cab; the hydraulic pump is often connected directly to the PTO



PTO



Pump

## Actuator

The hydraulic fluid, pump and power source generate flow and pressure. As described in the first section of this module, this pressure needs to be converted back to force and displacement. This is the job of the actuator.

Actuators can be classified into two types:

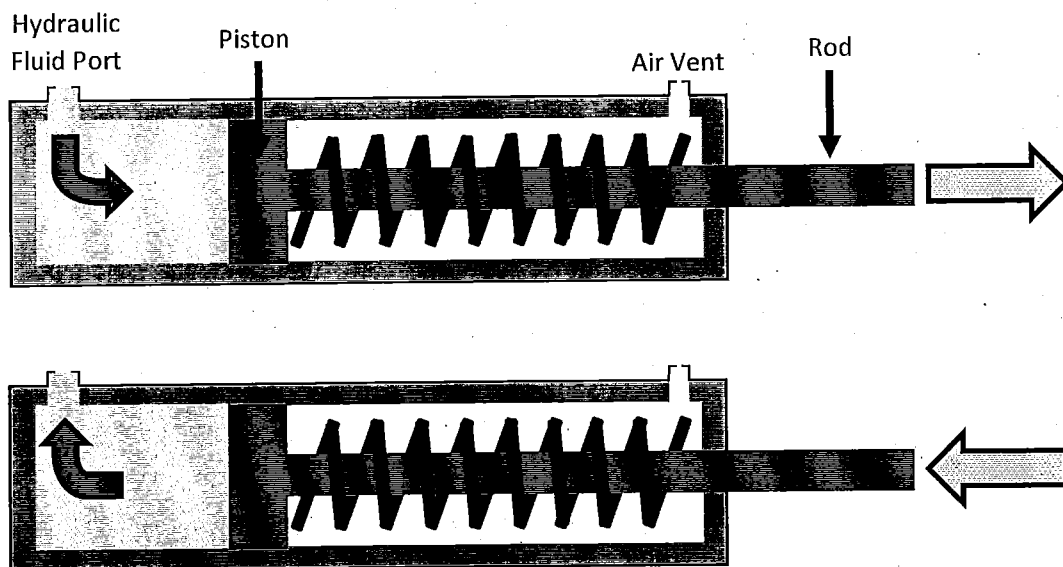
- **Linear (hydraulic cylinders)** – convert pressure and flow into linear force and displacement
- **Rotary (hydraulic motors)** – convert pressure and flow into torque and angular displacement

Hydraulic motors are used for a variety of things in the fire service. Two common examples are rotation of aerial ladders and hydraulic winches. Hydraulic cylinders control extension and elevation of aerial ladders and many of the hydraulic tools on rescue squads and other rescue apparatus.

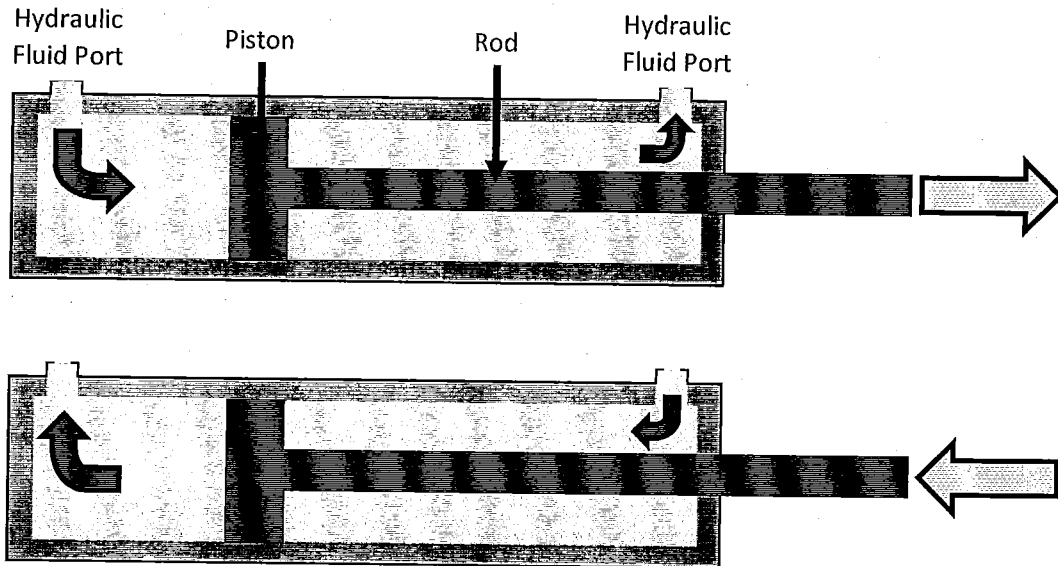
### Types of Hydraulic Cylinders

There are two common types of hydraulic cylinders:

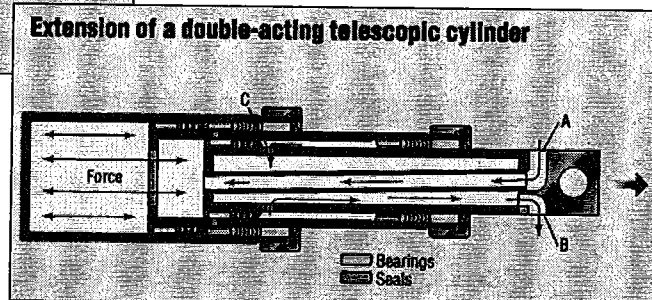
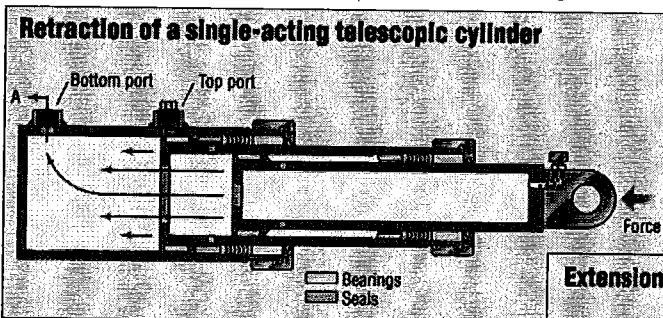
- **Single-Acting** – This type of cylinder is unidirectional (operates in one direction). Hydraulic fluid flows into the head of the cylinder through a single port and pushes on the piston, extending the rod. To retract the piston, a valve must be opened to allow fluid to flow back to the reservoir. The piston retraction is made possible either by gravity, the weight of the load or a mechanical force, such as a spring. Examples of single-acting cylinders are floor jacks and bottle jacks.



- **Double-Acting** – This type of cylinder is bidirectional (operates in two directions). Unlike single-acting cylinders, there are two ports on a double-acting cylinder, one at each end. To extend the piston, fluid flows from the pump into the port at the cylinder head. As the piston extends, fluid on the opposite side of the piston exits the cylinder through the other port and returns to the reservoir. To retract the piston, a directional valve reverses the fluid flow. Most hydraulic rescue tools utilize double-acting cylinders.



One special design of a hydraulic cylinder is the **telescoping cylinder**. These cylinders contain multiple tubes of progressively smaller diameters nested within each other. Each individual tube represents a stage. Telescoping cylinders have the distinct advantage of increased length at full extension while maintaining a relatively short retracted length. These cylinders can be found in both single- and double-acting designs.



## Valves

The valves in a hydraulic system control the movement of hydraulic fluid. They are used to control flow between the reservoir and the pump, the pump and the actuator, and flow within the actuator itself.

Single-acting cylinders typically have a valve or set of valves to control flow between the reservoir, pump and the hydraulic cylinder. They also contain a valve that allows fluid to return from the cylinder to the reservoir.

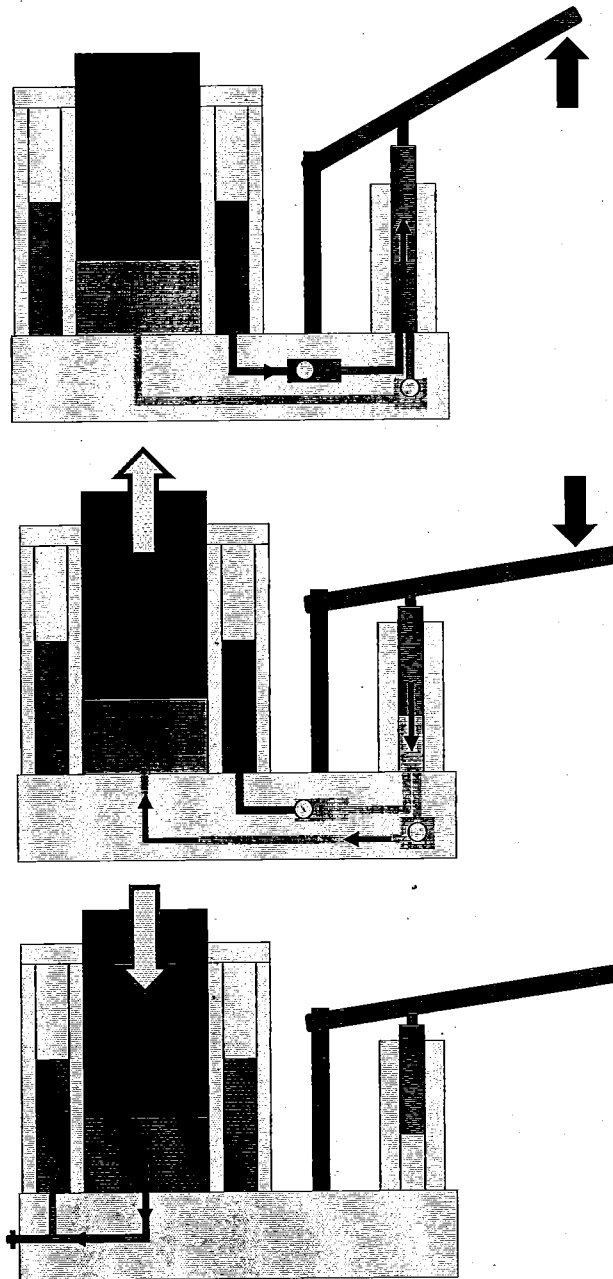
The diagrams on the right show the basic components of a bottle jack. They contain a single-acting cylinder and a reservoir that actually surrounds the cylinder. The pump is a reciprocating style that is manually operated.

Fluid flow between the reservoir and pump and the pump and cylinder is controlled by two ball valves.

In the top diagram, the ball valve between the reservoir and pump is open, allowing fluid to flow from the reservoir to the pump. The ball valve between the pump and cylinder remains closed.

In the middle diagram, the ball valve between the reservoir and pump closes while the ball valve between the pump and cylinder opens. This allows fluid under pressure to flow into the cylinder, creating lift.

The bottom diagram shows the operation of the release valve. This valve is opened to allow fluid to flow from the cylinder directly to the reservoir, enabling the piston to retract. Gravity along with the weight of the load and piston create the fluid movement.



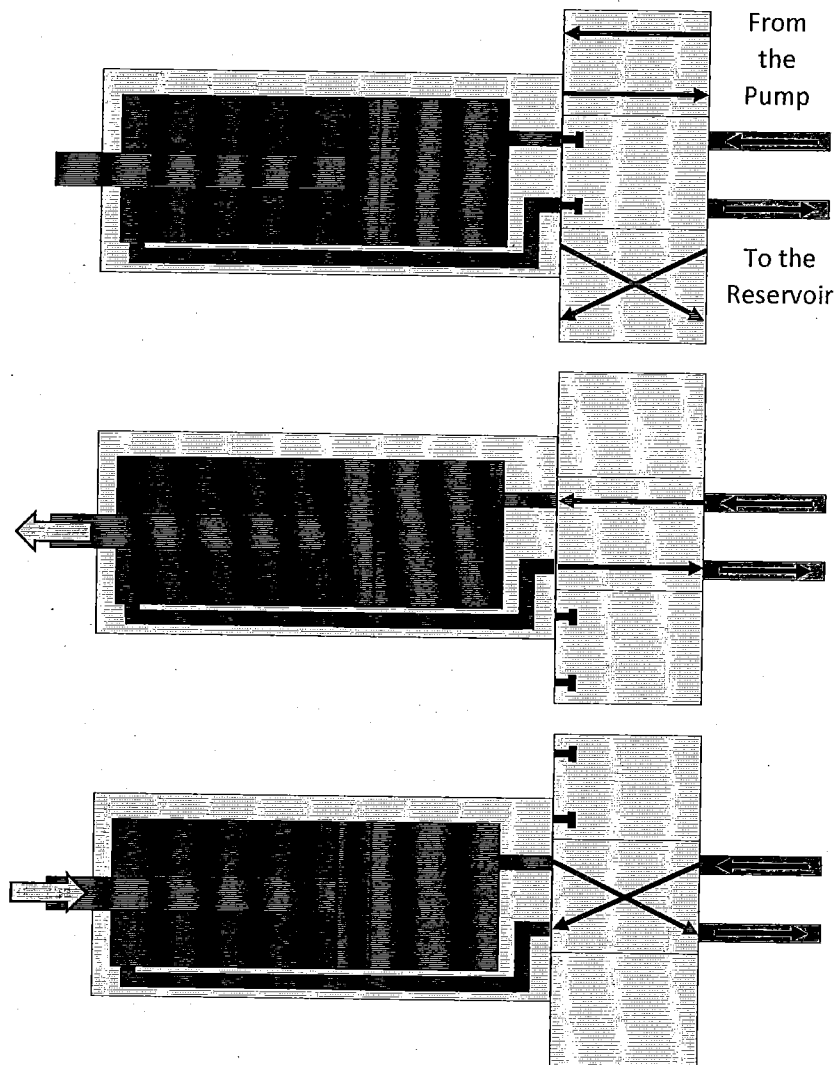
Double-acting cylinders, such as those on most hydraulic rescue tools, have a slightly different set of valves. One of the valves controls the direction of flow within the actuator. Another valve controls the flow between the reservoir, pump and actuator.

The diagrams on the right show the basic operation of the control valve on a hydraulic rescue tool. There are three different positions: Neutral, Extend and Retract.

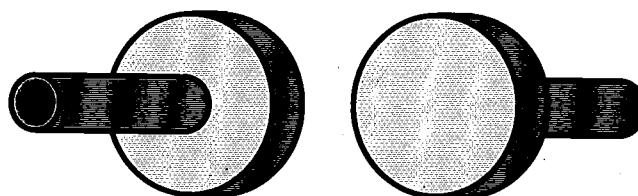
The top diagram shows the Neutral position. Fluid flow from the pump is blocked from entering the cylinder.

In the middle diagram, the tool operator rotates the control valve to the Extend position. Fluid is able to flow into the cylinder, pushing on the piston and extending the rod.

In the bottom diagram, the tool operator rotates the control valve to the Retract position. Fluid flow within the cylinder reverses direction. It now pushes on the opposite side of the piston, retracting the rod.

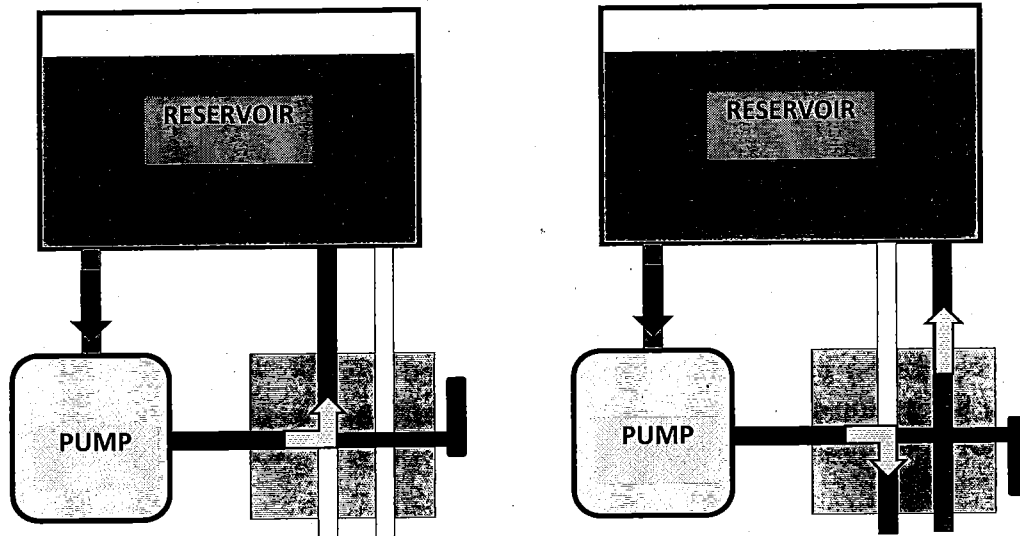


One noteworthy point about the double-acting cylinder shown above is that the surface areas on each side of the piston are not equal. The surface area on the left is decreased by the presence of the piston rod. This decrease in surface area results in a decrease in force applied through the piston rod during retraction.



Most hydraulic rescue tool systems also have a valve that controls the flow of hydraulic fluid to the tool. This valve has two positions. One position pressurizes the port going to the tool. The other position is a neutral, or “dump”, position that bypasses the tool port and recirculates (dumps) the hydraulic fluid back to the reservoir.

The diagrams below show the basic operation of the dump valve.



The diagram on the left shows the valve in the neutral position. Pressurized fluid from the pump is immediately returned to the reservoir. The diagram on the right shows the tool being pressurized. Hydraulic fluid flows from the pump, through the valve, to the tool and finally back to the reservoir.

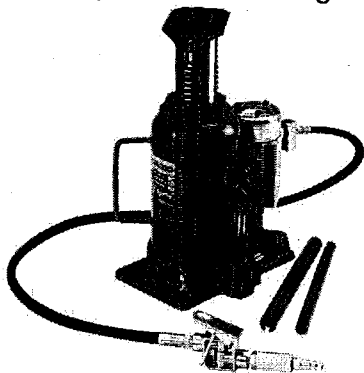
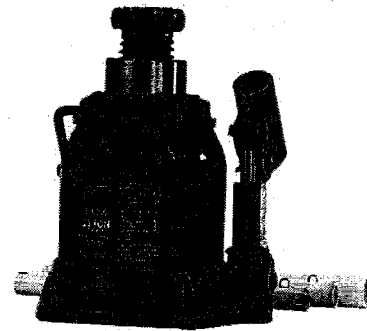
## Hydraulic Tools

### Manually Operated

Some of the most basic types of hydraulic tools carried on fire/rescue apparatus are actually not designed specifically for rescue applications. Instead, many manually operated tools are simply "borrowed" from other industries such as automotive repair.

#### Bottle Jacks

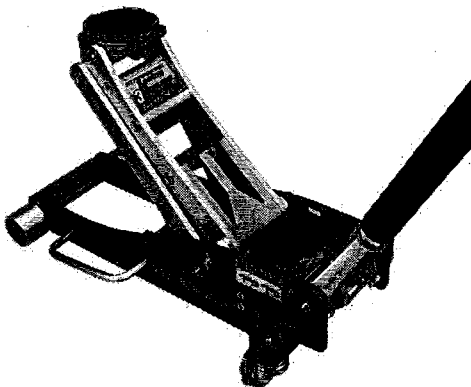
Bottle jacks are a single acting hydraulic cylinder controlled by a simple reciprocating pump and release valve. The handle on the pump provides the leverage needed to obtain the large output force with a relatively low input force. Bottle jacks can be either single piston or contain telescoping pistons. Many have a threaded post on top of the piston that can be extended for additional height prior to extending the piston.



Bottle jacks are designed for axial loading. Any side or eccentric loading could result in jack instability and/or possible hydraulic cylinder damage.

Capacities range from 1 ton up to 50 tons. Some bottle jacks are outfitted with a small pneumatic motor that can be used in lieu of the manual pump. These are called "air over hydraulic" bottle jacks.

#### Floor Jacks



Floor jacks are another type of single acting cylinder with a manually-operated reciprocating pump and release valve. The hydraulic cylinder is attached to an arm that pivots as it lifts, creating a Class 3 lever. The lifting point on a floor jack is called the saddle. As the hydraulic piston extends, the lifting arm pivots raising the saddle. However, the rotation of the lifting arm also causes the saddle to move horizontally as well as vertically. To compensate for this horizontal movement, floor jacks are mounted on wheels.

Capacities typically range from 1.5 tons up to 20 tons.

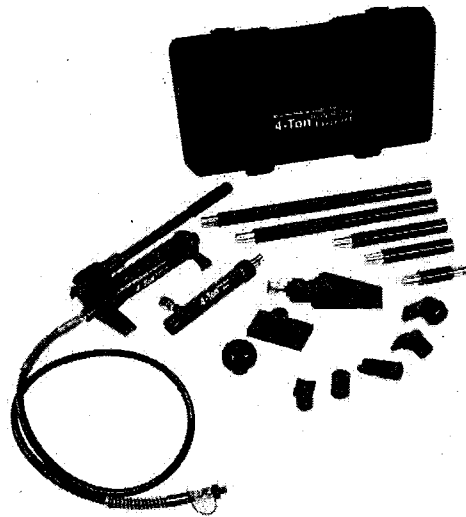
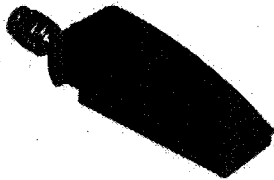
## Portable Hydraulic Kits

Commonly referred to as porta-power kits, manually-operated portable hydraulic kits are used in the automotive body repair industry. They consist



of a single action reciprocating hand pump and hydraulic hose. The pump can be connected to either a spreading tool or ram. The ram can be outfitted with extensions and various end attachments. These smaller hydraulic tools are useful in tight areas where larger hydraulic rescue tools may not fit.

Porta-power kits can range from 4-ton up to 20-ton capacities.

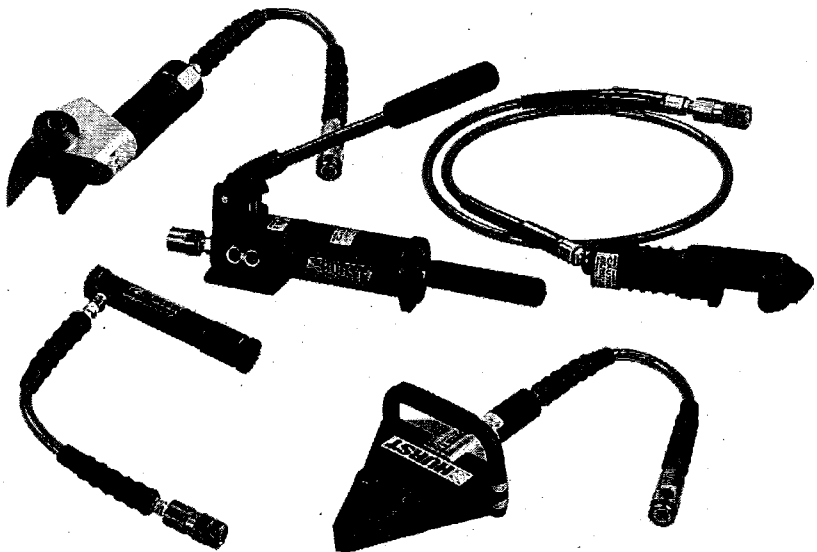


## Fire/Rescue Portable Hydraulic Kits

Many hydraulic rescue tool companies also manufacture manually-operated portable hydraulic kits. Just like those used in auto body repair shops, fire/rescue kits contain a manually-operated single action hydraulic pump and hose with various tools and attachments. One such kit is the Hurst Mini-Lite kit:

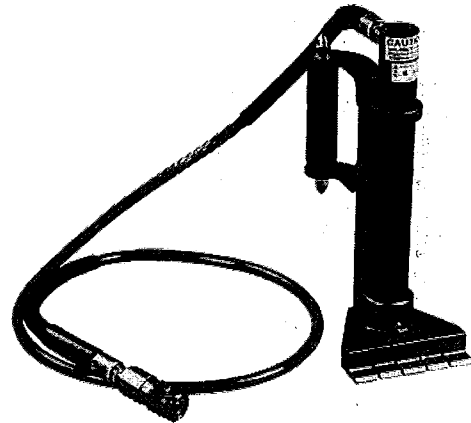
The Mini-Lite kit contains spreaders, cutters and rams. All of these tools are powered by a hand pump.

The cutters provide up to 13,000 and 17,000 lbs. of cutting force. The spreaders are rated for 7,300 lbs. of spreading force. Rams can provide up to 10,000 lbs. of force.



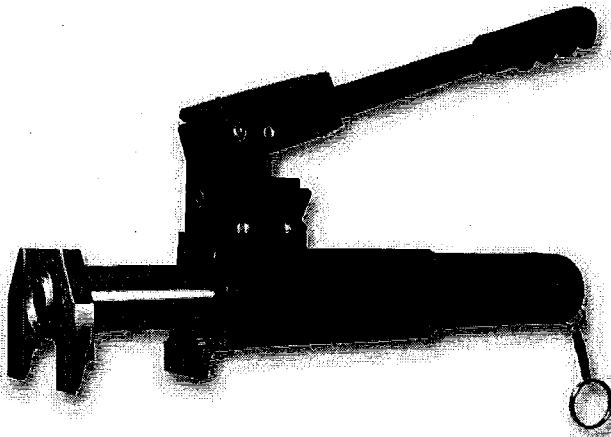
### Rabbit Tool

The Rabbit Tool is designed for forcible entry applications. It works with the same Hurst Mini hand pump that is used with the Mini-Lite kit and can provide up to 8,000 lbs. of spreading force. The standard Rabbit Tool provides 4 inches of spreading distance. The larger JL-8 Jack Rabbit Tool doubles that spreading distance to 8 inches.



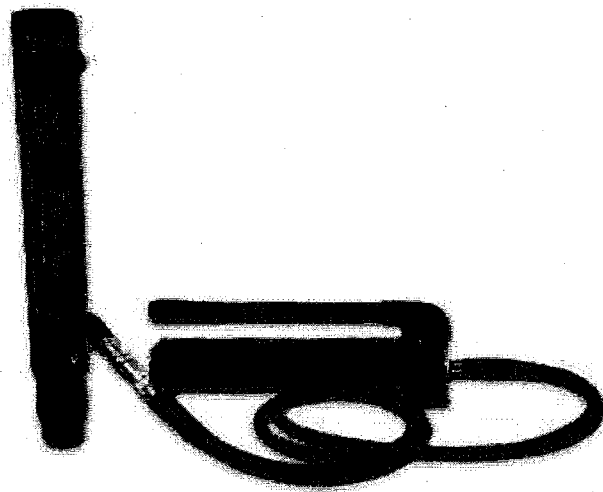
### Hydra-Ram

The Hydra-Ram is another forcible entry tool. Developed by Fire Hooks Unlimited, it is very similar to the Rabbit Tool in operation. However, unlike the Hurst design, the Hydra-Ram eliminates a separate pump and hose. Instead, the hydraulic pump and actuator are integrated into a one-piece tool. Two varieties of the tool exist: the Hydra-Ram with 4 inches of spreading distance and the Hydra-Ram II with 6 inches of spreading distance. Both are rated for up to 10,000 lbs. of spreading force.



### Paratech HydraFusion Struts

Another fire/rescue-specific hydraulic tool is the HydraFusion strut designed by Paratech. These struts are a combination of a standard Paratech strut used for stabilization and a hydraulic ram. HydraFusion struts are powered by a separate manually-operated hydraulic pump. They are rated for 10 U.S. tons of lift with a safety factor of 2:1. Three different sizes of HydraFusion struts provide lifting/spreading distances of 4, 10, and 16 inches.



## Hydraulic Rescue Systems

### Types

Hydraulic rescue tool systems are generally identified by their operating pressures. There are two categories: low pressure and high pressure. While there are some similarities, each type of system has unique features and benefits:

#### Low Pressure

- Operating Pressure: 5,000 psi
- 2-Stage Pumps
- Tools are often heavier than high pressure tools
- Tools tend to operate slower than high pressure, which can provide more precise control and movement

#### High Pressure

- Operating Pressure: 10,000+ psi
- 2-Stage Pumps
- Tools are often lighter than low pressure tools
- Tools tend to operate faster than low pressure, which can provide speed but may make precise control and movement difficult

In both low and high pressure systems, the tools themselves are very similar in function and appearance.

The difference is in the pump. Hurst patented the first hydraulic rescue system, the Jaws of Life®, in the

1970's. It was based on the same principles of fluid mechanics and Pascal's Law outlined at the beginning of this module. Hurst's 5,000 psi rescue systems are still widely used today. Advances in technology and a demand for lighter, faster tools led to the introduction of high pressure systems. As the examples using Pascal's Law demonstrated, the output force of the hydraulic system is dependent upon the fluid pressure and the surface area of the piston. Increasing the operating pressure from 5,000 psi to 10,000+ psi meant that

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RESCUE SYSTEMS

tool pistons could be smaller and still produce the same force as 5,000 psi tools. One of the trade-offs is that high pressure tools must be manufactured with materials and components that will withstand the higher operating pressure. AMKUS is one of the leading manufacturers of high pressure rescue systems. Others include Genesis and Holmatro. Even Hurst manufactures a line of 10,000 psi rescue tools.

 **HURST**  
**JAWS OF LIFE®**

**GENESIS**  
RESCUE SYSTEMS

 **holmatro**  
rescue equipment

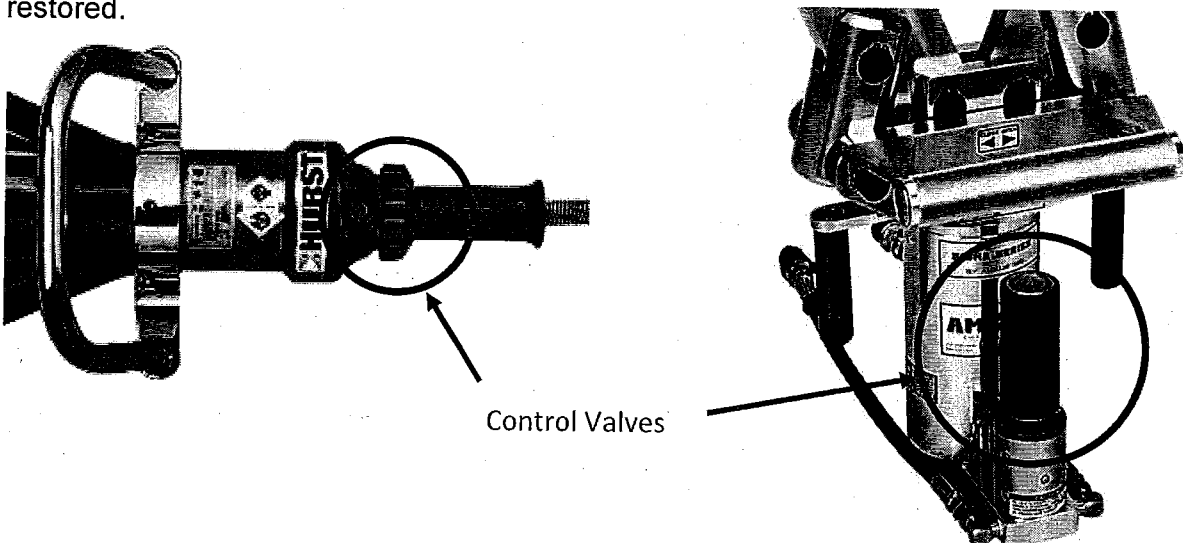
## Operation

Most hydraulic rescue systems incorporate 2-stage pumps (Holmatro uses a 3-stage axial pump). Hydraulic tools will perform differently based on differences in hydraulic fluid pressure and flow. Higher pressures result in higher output force from the tool. Higher fluid flows result in faster piston movement and tool operation. Unfortunately, both cannot be achieved at the same time. Increases in hydraulic fluid pressure mean a decrease in flow rate. Likewise, increases in fluid flow rate result in decreases in pressure. The key is gaining both benefits from one pump and tool, and hydraulic rescue tool manufacturers have done just that.

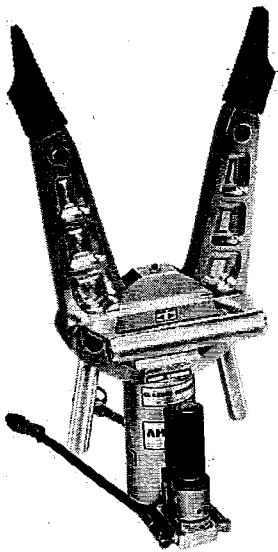
Hydraulic tool users want maximum speed when operating tools that are not under load (e.g. opening cutter blades). To allow this, the hydraulic pump operates in the low pressure/high flow stage (often called Stage 1). Once the tool meets resistance, the hydraulic pump automatically switches to the high pressure/low flow stage (Stage 2) to provide the maximum operating pressure for the tool. Hydraulic tool operators will sometimes notice this switchover represented by a brief pause in tool operation when it meets resistance followed by movement to finish the spread/cut.

Some manufacturers are now incorporating “turbo” or “boost” modes into their pump designs. The idea behind this design is that it allows a user to double the quantity of fluid being supplied to a single tool. The increase in fluid will increase the operating speed of the connected tool during both pump stages.

The majority of hydraulic rescue tools utilize a “dead man” control valve. This valve is designed to revert back to the Neutral position once the operator releases his/her grip. This prevents unintended movement of the tool when not in use. They also incorporate check valves to prevent loss of pressure in the tool should fluid flow be interrupted (e.g. a hydraulic line or pump fails). This allows the tool to hold the load until fluid flow can be restored.



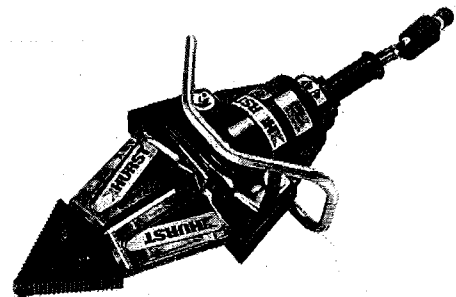
## Spreaders



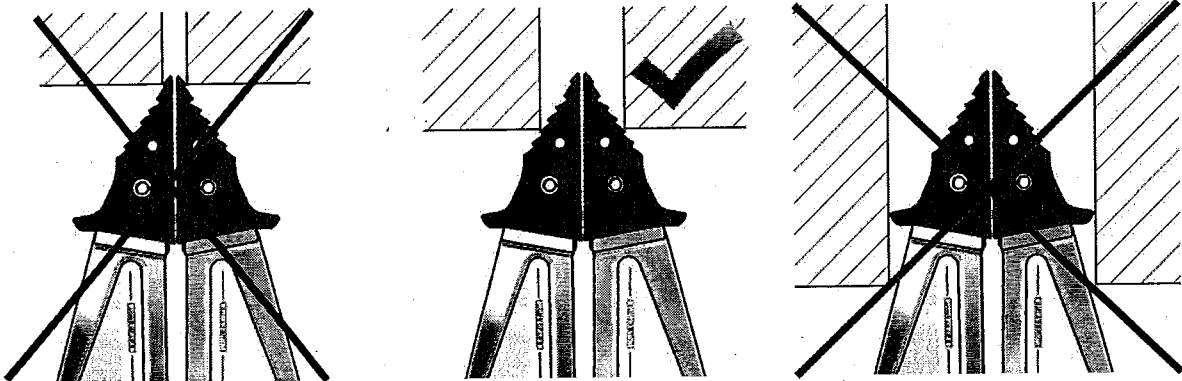
Spreaders use a set of arms connected to a piston rod to apply outward force at the tip of each arm. They can be used for prying and spreading as well as lifting. Spreaders come in different sizes with varying arm lengths. Longer arms provide greater spreading distance at full opening. However, this typically results in a decrease in maximum spreading force.

Spreaders utilize a double acting cylinder so force is applied to the arms as they are both opening and closing. This closing force can be used to pull and pinch objects. One thing to note is that the closing force will be less than the opening force. This is due to the fact that the surface area of the piston is not equal on both sides. The double acting cylinder example from earlier in the module shows this difference.

There are a variety of different spreader tip designs and accessories. Some tips are designed for gripping surfaces while others are used for peeling. Many tips have holes drilled through them for mounting chains to be used in pulling applications.



Whenever spreading, it is important to obtain a good grip with the tips. Spreading should **ONLY** be done at the tips – using the arms of the tool will result in damage.



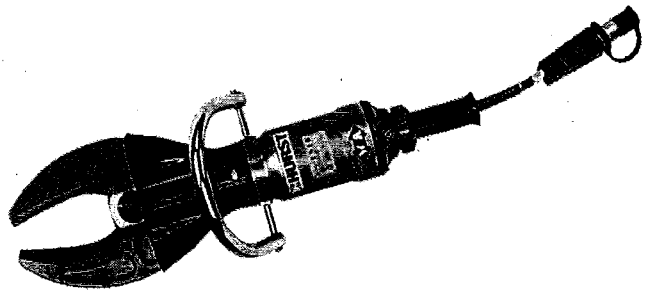
“Maximum spreading force” is often advertised by manufacturers to promote their tools. However, one problem with these numbers is that they are obtained by the individual manufacturers who do not necessarily use the same test methods as other manufacturers. To help remedy this issue, NFPA 1936 – Standard on Powered Rescue Tools outlines specific testing guidelines for NFPA-compliant rescue tools.

## Spreaders (continued)

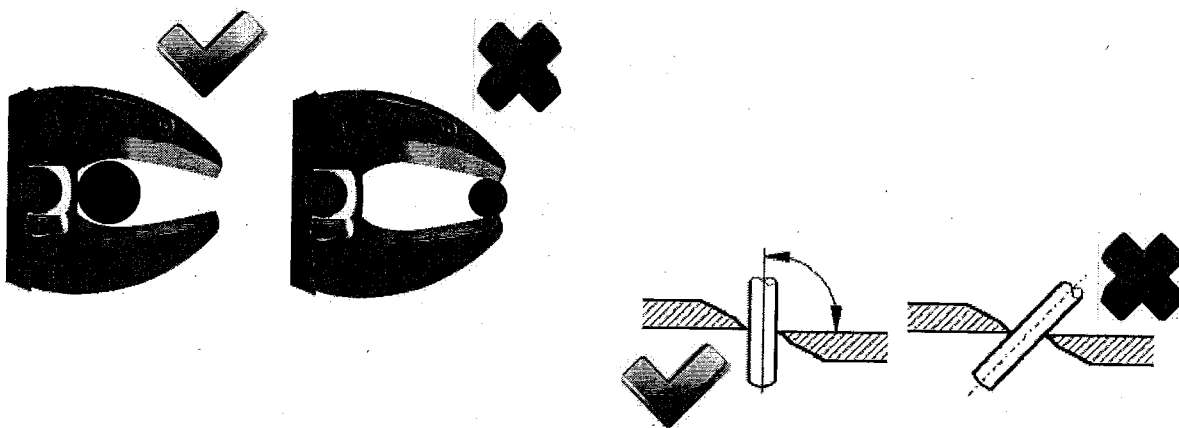
In this test, the holes used for pulling attachments provide the test points. The spreading force exerted by the tool is measured at 10 uniformly spaced intervals that range from the fully closed position to 95% of the fully open position. The measured forces are then converted to a value for force at the tool tip using a specified calculation. The lowest calculated spreading force of all 10 test points is designated as the LSF (Lowest Spreading Force) for that tool. The highest calculated spreading force of all 10 test points is designated as the HSF (Highest Spreading Force) for the tool. The test is then conducted for pulling force, yielding LPF and HPF values.

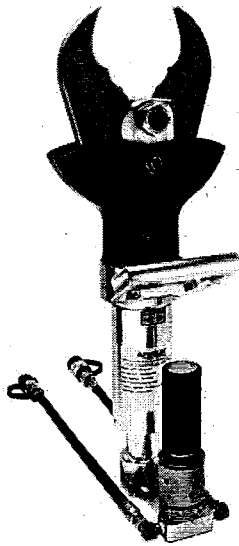
## Cutters

Cutters act as hydraulic scissors to cut through various metals. Similar to spreader arms, cutters contain two pivoting cutting blades connected to a piston rod. The design of the cutter blades dictate the size, shape and strength of materials that can be cut.








Although cutters also utilized double acting cylinders, they are not designed for use in both directions. Their sole function is to cut. The greatest cutting capacity is achieved when the cut is performed as close to the blades pivot point as possible (often referred to as the "notch"). Also, to avoid damage, the cutting blades should be positioned at 90° to the object to be cut.





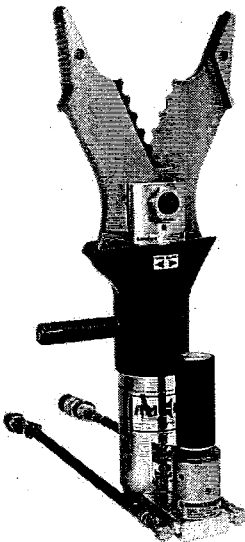
NFA 1936 also provides testing procedures and ratings for cutters. In this test, the cutter is tested with six different types of material. It is assigned a rating based on the thickness of material that it is able to completely sever in a single continuous motion. To be NFA compliant, the cutter must complete a minimum of 60 qualified cuts.

Material Category	A Round Bar 	B Flat Bar 	C Round Pipe 	D Square Tube 	E Angle Iron 
Material	A-36 Hot-Rolled	A-36	Schedule 40 A-53 Grade B	A-500 Grade B	A-36
Performance Level	Diameter (in.)	Thickness x Width (in. x in.)	Nominal Size (in.)	Dimension x Wall Thickness (in. x in.)	Square Dimension x Thickness (in. x in.)
1	3/8	1/4 x 1/2	3/8	0.68 x 0.09	1/2 x 1/8
2	1/2	1/4 x 1	3/4	1.05 x 0.11	1 x 1/8
3	5/8	1/4 x 2	1	1.32 x 0.13	1 1/4 x 3/16
4	3/4	1/4 x 3	1 1/4	1.66 x 0.14	1 1/2 x 3/16
5	7/8	1/4 x 4	1 1/2	1.90 x 0.15	1 1/2 x 1/4
6	1	3/8 x 3	2	2.38 x 0.15	1 3/4 x 1/4
7	1 1/4	3/8 x 4	2 1/2	2.88 x 0.20	1 1/2 x 3/8
8	1 1/2	3/8 x 5	3	3.50 x 0.22	2 x 3/8
9	1 3/4	3/8 x 6	3 1/2	4.00 x 0.23	2 1/2 x 3/8

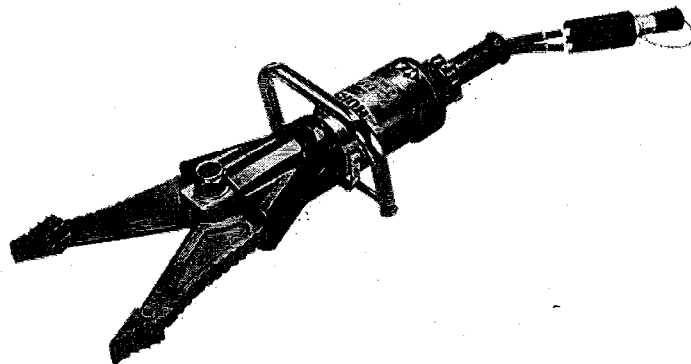
An example of a NFA cutter rating would be A7/B9/C7/D8/E9.

## Combination Tools

Combination tools are hybrids of a spreader and cutter. They are designed to be a multifunctional tool with both spreading and cutting capabilities. Combination tools may not provide the optimum performance of a job-specific tool like a spreader or cutter, but they offer flexibility and extrication options in an all-in-one package. As with spreaders and cutters, combination tools are equipped with various sizes and designs of blades.



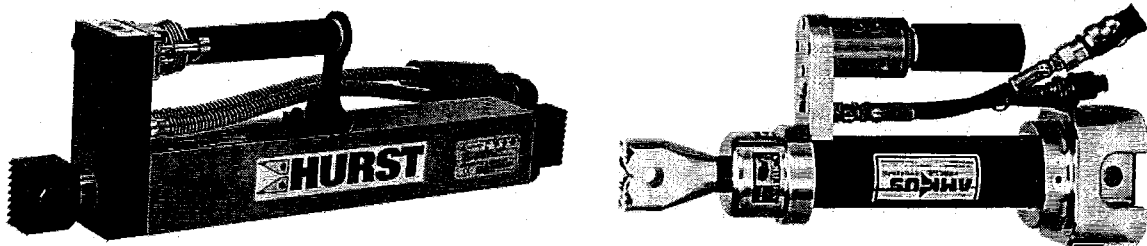
To be NFA compliant, combination tools must undergo testing as both a spreader AND a cutter. Therefore, it will carry both sets of ratings.



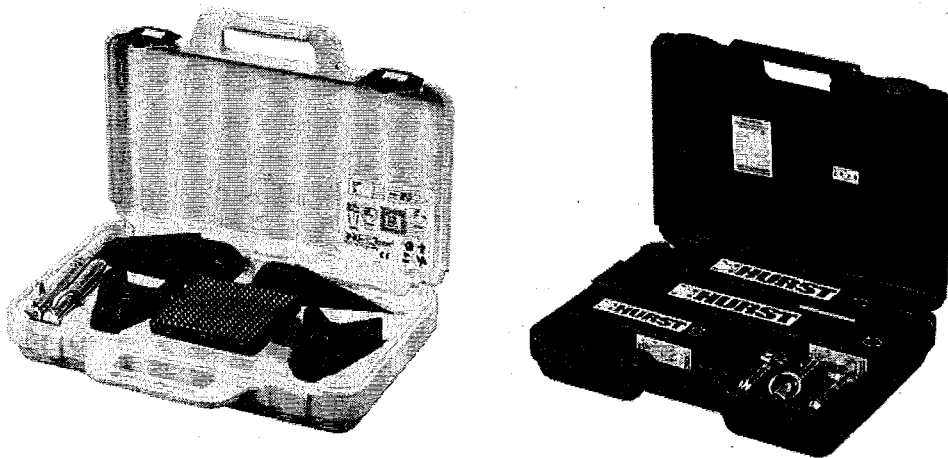
## Rams

Rams are used for pushing and/or pulling. Unlike spreaders that use pivoting arms, rams utilize only the piston rod to apply linear force. Rams come in a variety of lengths to meet different applications.

Some rams utilize double acting hydraulic cylinders to apply both pushing and pulling force. As mentioned previously, the double acting cylinder will apply more force in one direction. In the case of a ram, the largest force is applied during the push. Pulling force is approximately 50% of the pushing force due to the reduction in surface area on the opposite side of the piston.

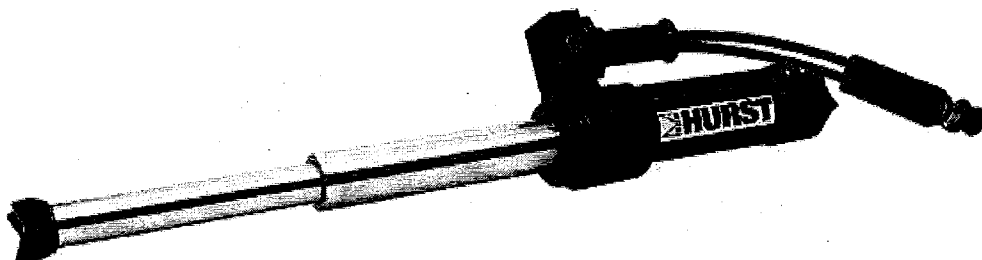


Some rams come with attachments for additional functionality. Different bases and tips provide either grip or piecing/cutting capabilities. Ram extensions can also be used to increase the range of the ram.



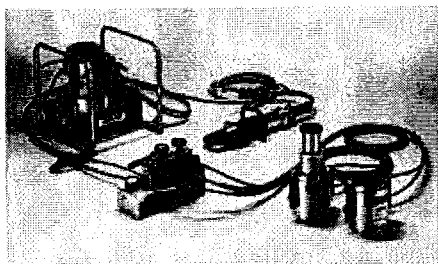
The NFPA 1936 testing procedure for rams is similar to that for spreaders. The spreading force exerted by the ram is measured at 3 uniformly spaced intervals between the fully retracted position and 95% of the fully extended position. The recorded values will be used to determine the spreading forces, HSF and LSF. If the ram is capable of pulling, the test will be repeated to determine HPF and LPF values.

Another type of ram is the telescoping ram. The 2-stage telescoping action of these rams provide the benefit of increased stroke length while maintaining a relatively small retracted storage length. The 1<sup>st</sup> stage of extension provides the maximum pushing capacity. Capacity decreases as the 2<sup>nd</sup> stage engages because the second piston has less surface area than the combination of both pistons in the 1<sup>st</sup> stage.



Telescoping rams are only designed for pushing. They undergo the same testing requirements as other rams to achieve NFPA compliance.

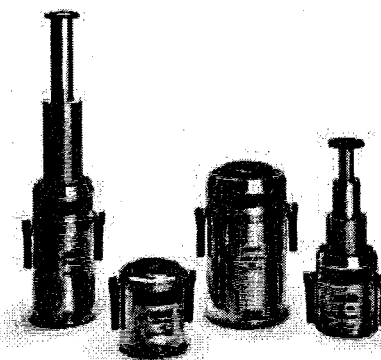
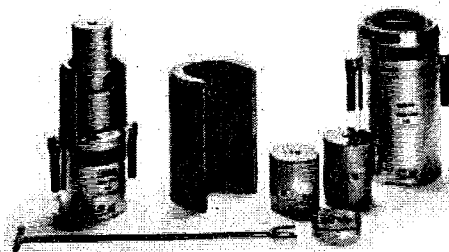
### Hurst Lift Cylinders



The Hurst telescopic lifting cylinders are a type of specialized hydraulic rescue tool. They operate much like a telescoping bottle jack. However, instead of being powered by a hand pump, the Hurst lift cylinders are powered by the Hurst hydraulic system. The higher operating pressures lead to high lifting capacities. Lift cylinders operating on a 5,000 psi system have

maximum capacities of just over 96,000 lbs. while cylinders on a 10,000 psi system top out at over 141,500 lbs.

The narrow profile of Hurst lift cylinders make them perfect for applications where large high pressure air bags may not fit (e.g. under rail and METRO cars). The lift cylinders come in 2- and 3-piston models. Numerous attachments and accessories are included with a lift cylinder setup. Hurst lift cylinder operation is more complicated than that of standard hydraulic rescue tools. Proper training from a qualified instructor is highly recommended before use.



## Tool Maintenance and Inspection

Hydraulic rescue tools should be inspected on a daily basis and after every use. Visual inspection items include:

- Check general tightness (presence of leaks)
- Existence and stability of the handle
- Covers in good condition
- Spreader and cutter arms are free of cracks and without any chipped spots or deformations
- Cutting blades are free of large gouges
- Spreader tips are securely attached and free of damage

Operational checks should include:

- Ensure the control valve moves freely and is not damaged/leaking and that it returns to the neutral position appropriately
- Operate the tool through its full range of motion and check for:
  - Suspicious noises
  - Hydraulic fluid leaks
  - Unusual movement of spreader arms or cutter blades
- Ensure that the tool does not continue to operate when the dead man control valve returns to the neutral position
- Ensure that cutting surfaces on cutter blades slide over one another and do not make contact

Following use, hydraulic tools should be wiped down with a clean towel. If necessary, a damp rag along with a mild cleaner/degreaser can be used to remove dirt, oil or other contaminants. All components should be immediately dried to prevent corrosion. Do not apply any oils or lubricants to cutter blades as this can lead to loosening of the pivot bolt.

Hydraulic pumps and hoses should also be visually checked prior to operation. Any damage or leaks require repair or replacement prior to use. Couplings should be free of dirt and debris. If necessary, they can be cleaned with a solution of soap and warm water and then rinsed and dried. Fluid levels in pump reservoirs need to be checked and topped off if necessary. Do not overfill reservoirs and only use the manufacturer-approved hydraulic fluid.

All service and repair of hydraulic rescue systems should be handled by a qualified service technician.

# SHORING & STABILIZATION

## Introduction

Rescue personnel within the fire service are accustomed to using shoring on a regular basis. The broad definition for shoring is the temporary support of structures during construction, demolition, reconstruction, etc. in order to provide stability that will protect property as well as workers and the public.

In the fire service the definition would also include:

- temporary support of structures, vehicles and objects during emergency incidents and training
- to provide stability
- to remove the suspension qualities of a vehicle
- to bring an object to a solid state
- to minimize the hazards associated with movement of objects
- to protect rescuers, victims and property

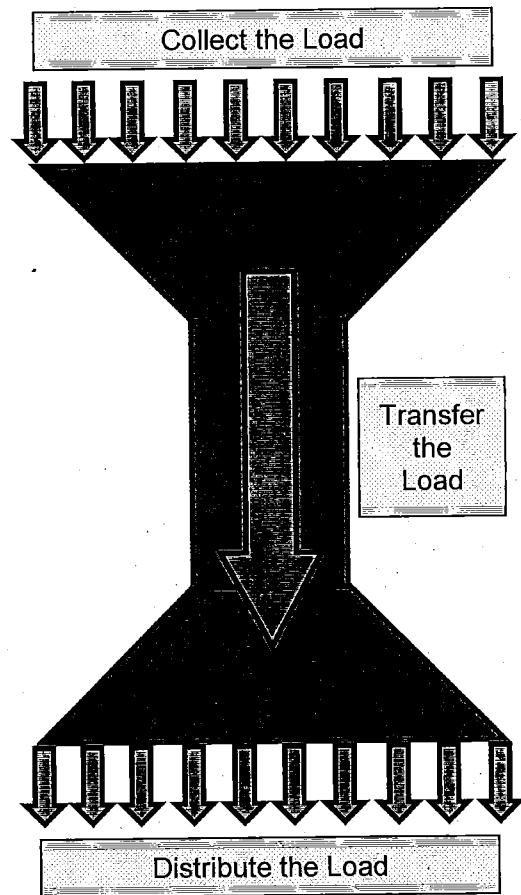
## Basic Principals

The basic principal behind the use of shoring can be compared to a double funnel:

1. The top of the funnel collects the load from the object that is being supported.
2. The middle of the funnel transfers the load to the bottom of the funnel.
3. The bottom of the funnel distributes the load across the ground or other supporting structure.

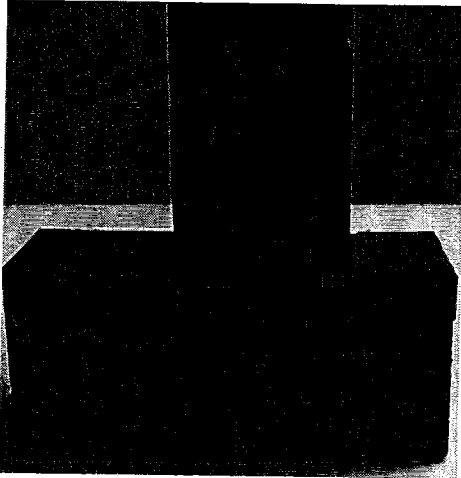
If the double funnel approach is not used and a large load is placed completely on the center of the "funnel," the center item can punch through the load it is trying to support.

Viewed in relation to the fire service, wood cribbing and pneumatic struts use the double funnel approach to shoring.



## Wood Construction & Capacities

### Features



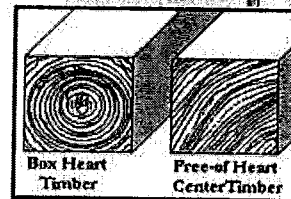
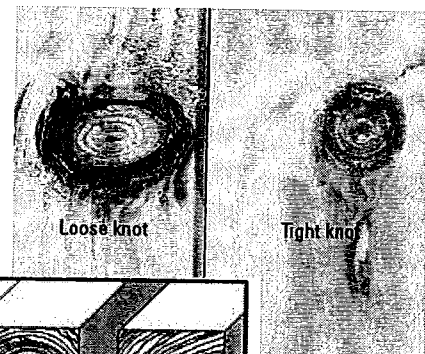
One of the most desirable features of emergency shoring is that it provides the rescuer warning signs when it is becoming overloaded. These warnings will allow the rescuer to mitigate the situation, be that installing additional shoring material or the evacuation of the area.

Wood inherently has a warning signal built in (or "grown in"). When wood shoring material starts being overloaded, it will begin to crush as well as produce the audible warning of groaning. Wood cribbing can crush up to 20% of its height before failing.

### Strength

The strength of a specific piece of wood depends on several factors including the species of wood, the moisture content, the length and the thickness. When evaluating species of wood for use as cribbing one should look for:

- A minimum of 8 growth rings per inch
- A tight knot no more than 1 ½" in diameter
- A loose knot no more than ¾" in diameter
- No box heart timber

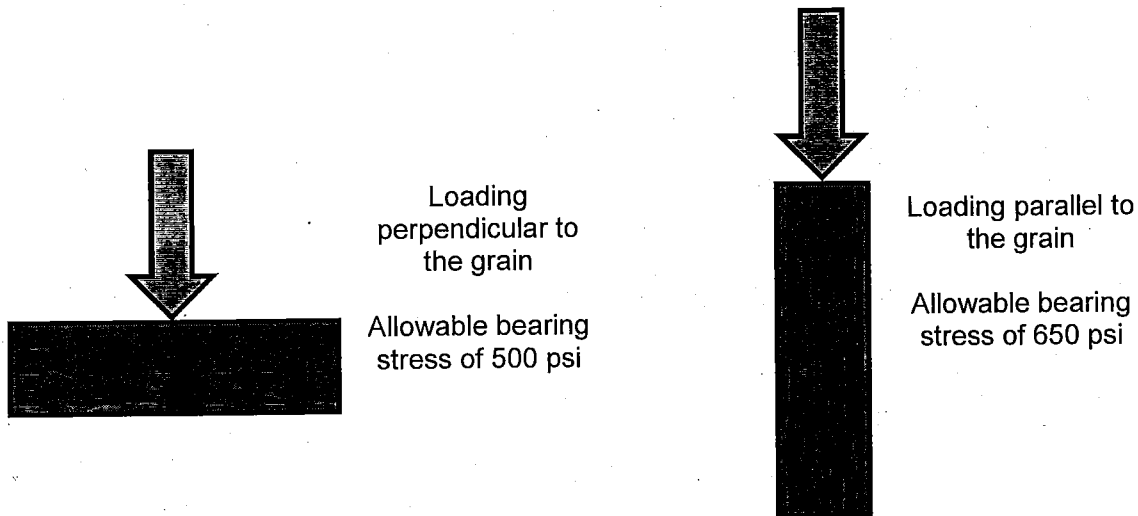


Based on their core material properties, soft woods such as Douglas Fir and Southern Pine are the most common types of lumber used for emergency shoring/cribbing. The table below compares the characteristics of Douglas Fir and Oak.

Douglas Fir	Oak
<ul style="list-style-type: none"><li>• Relatively lightweight</li><li>• Inexpensive</li><li>• Douglas Fir is the most common type of lumber in the U.S.</li><li>• Gives warning of overload.</li><li>• Disposable.</li><li>• Good for unknown loads</li></ul>	<ul style="list-style-type: none"><li>• Twice as heavy as Douglas Fir</li><li>• Expensive</li><li>• Splinters and warps</li><li>• Oak family varies</li><li>• May have catastrophic failure</li><li>• 1.5x stronger than Douglas Fir</li><li>• Good for known loads</li></ul>

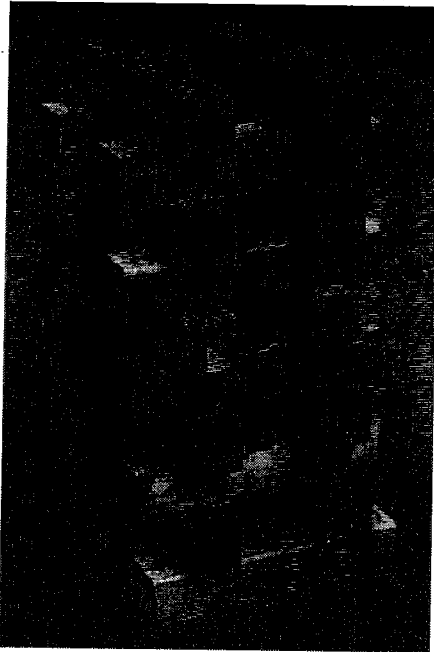
Strength (continued)

The strength of a piece of wood is dependent upon the direction of loading – either parallel or perpendicular to the grain. For Douglas Fir or Southern Pine, the allowable bearing stress parallel to the grain (longitudinal grain) is around 650 psi. For the same species of wood, the allowable bearing stress perpendicular to the grain (cross grain) ranges from 300 psi to 700 psi. (The average of 500 psi is used for load calculations).



The manner in which a piece of wood will fail under load is also dependent upon the direction of loading. While bearing stress may be higher parallel to the grain, the failure mode is undesirable in this configuration. Longer wooden posts overloaded along the longitudinal grain can buckle and fail suddenly. Conversely, when the wood is overloaded on the cross grain, crushing is observed both visually and audibly. This provides the early warning that is desirable in the emergency shoring environment.

## Cribbing



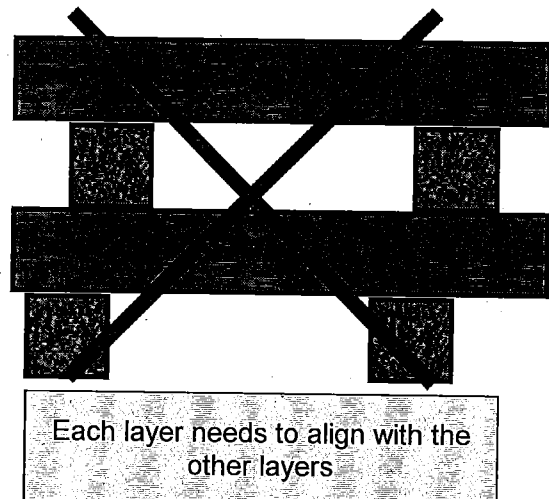
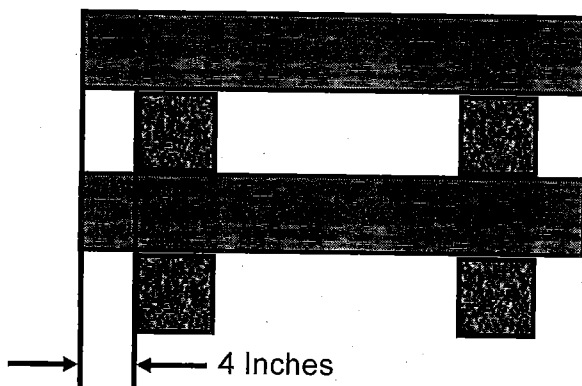
The fire service rescue squad cannot carry large quantities of 10" x 10" shoring material. To obtain the necessary height that is often needed, multiple pieces of smaller wood can be stacked upon each other to create a "pile" of wood. Of course simply placing the wood together in a pile does not create a stable foundation to support the load. To achieve the goal of creating a taller shore from small pieces we must create a box crib.

The box crib will resemble "Lincoln Logs," the children's tool erector set. Stacking two layers of cribbing perpendicular to one another starts to create the "box." Adding additional layers following the same crisscross pattern will allow the box to grow.

The stability of the box crib will depend on the dimensional size of the wood used to create the crib.

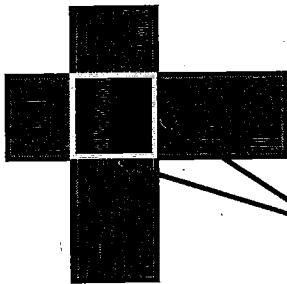
The maximum height to width ratio is 3 to 1. The "width" is referring to the width of the box crib itself, not the length of the lumber used to construct it. This will be discussed in more detail later. The height limitations on box cribs are due to lateral stability. Testing done by the U.S. Army Corps of Engineers (USACE) has shown that stability is an issue in tall box cribs. Knowing this, the height to width ratio should be reduced to 2:1 when working with free, laterally unstable objects. Based on this testing, it is recommended to limit the height of box cribs using 4x4 lumber to 4 feet and cribs using 6x6 lumber to 6 feet.

The building of the box must be methodical so as to build a symmetrical box. When placing one piece of wood on top of another, the corners should be overlapped by a minimum of 4" to guard against splitting of corners of individual pieces and compromising the stability of the box.



The point on a box crib where two pieces of cribbing overlap is referred to as a "Point of Contact". These points of contact are what support and carry the load. This load carrying capacity is based on two things: the surface area of the point of contact and the bearing stress of the wood used.

The surface area is calculated by multiplying the length of the point of contact by the width. Dimensional lumber has two sizes: nominal and actual. Historically, the nominal dimensions were based on green, unfinished boards. After the wood was dried and planed, the finished, or actual, dimensions were smaller. Modern lumber is still referred to by nominal dimensions (e.g. 2x4, 4x4, 4x6, 6x6) but actual dimensions are smaller. So, a 4x4 piece of lumber purchased at a hardware store is actually closer to 3½" x 3½" and a 6x6 is approximately 5½" x 5½".



**Surface Area of a Point of Contact**

$$4 \times 4 = 3\frac{1}{2}'' \times 3\frac{1}{2}'' = 12.25 \text{ in}^2$$

$$6 \times 6 = 5\frac{1}{2}'' \times 5\frac{1}{2}'' = 30.25 \text{ in}^2$$

As mentioned previously, the allowable bearing stress perpendicular to the grain for Douglas Fir and Southern Pine is 500 psi. So the calculations for capacity are as follows:

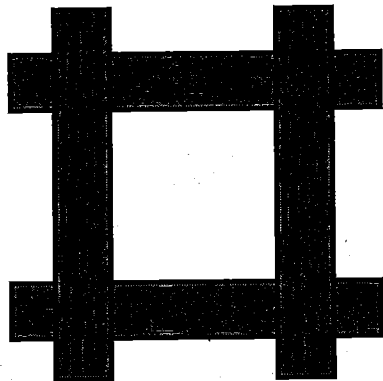
**Load Carrying Capacity of a Point of Contact**

Capacity = Surface Area x Bearing Stress

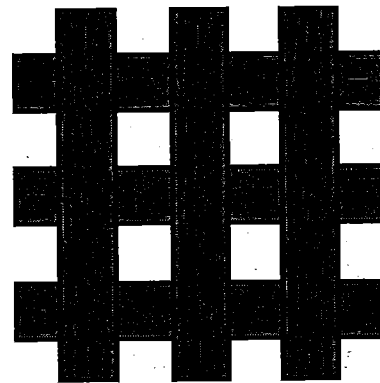
**4x4:** Capacity = 12.25 in<sup>2</sup> x 500 psi = 6,125 lbs.

**6x6:** Capacity = 30.25 in<sup>2</sup> x 500 psi = 15,125 lbs.

For ease of calculating crib capacities, round these numbers down to 6,000 lbs. and 15,000 lbs. Thus, the point of contact between two 4x4's will support 6,000 lbs. and the point of contact between two 6x6's will support 15,000 lbs. To obtain the overall crib capacity, add the capacity of the individual points of contact.



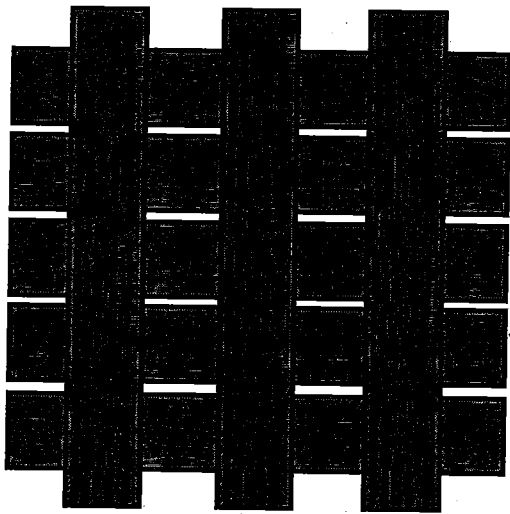
**2 by 2 Box Crib:** 4 Points of Contact  
24,000 lbs. (4x4) and 60,000 lbs. (6x6)



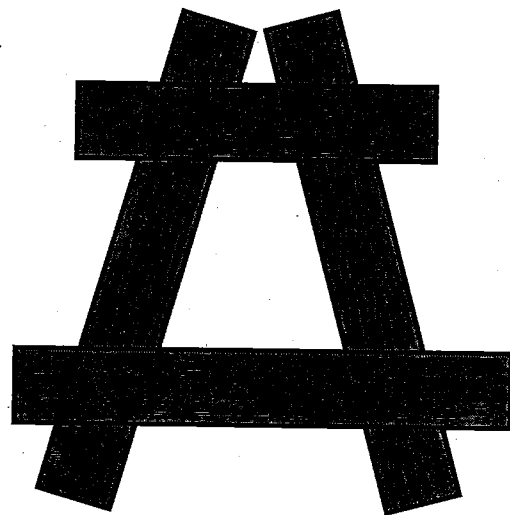
**3 by 3 Box Crib:** 9 Points of Contact  
54,000 lbs. (4x4) and 135,000 lbs. (6x6)

Rescue conditions will dictate how to construct a box crib. For example, when placing an air bag on top of box crib you want/desire a solid platform to support the airbag. A solid platform should also be used on the bottom of the crib any time the crib is not on a solid base (such as concrete). The load carrying capacity of the box crib is determined by the **minimum** number of contact points throughout the crib, not the number at the solid platform.

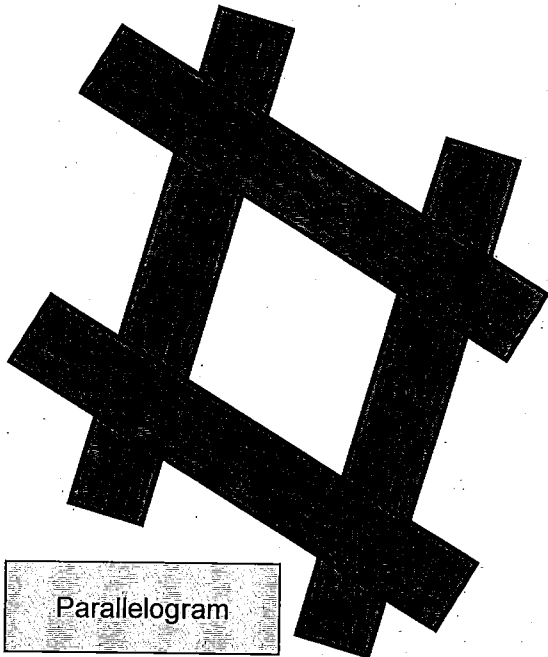
Although the design and shape of the crib should be symmetrical whenever possible, other configurations are possible. As shown in the pictures below, a triangular or parallelogram crib is possible. As these cribs are not as stable, the height to width ratio should be kept at 1:1.



Solid Bearing

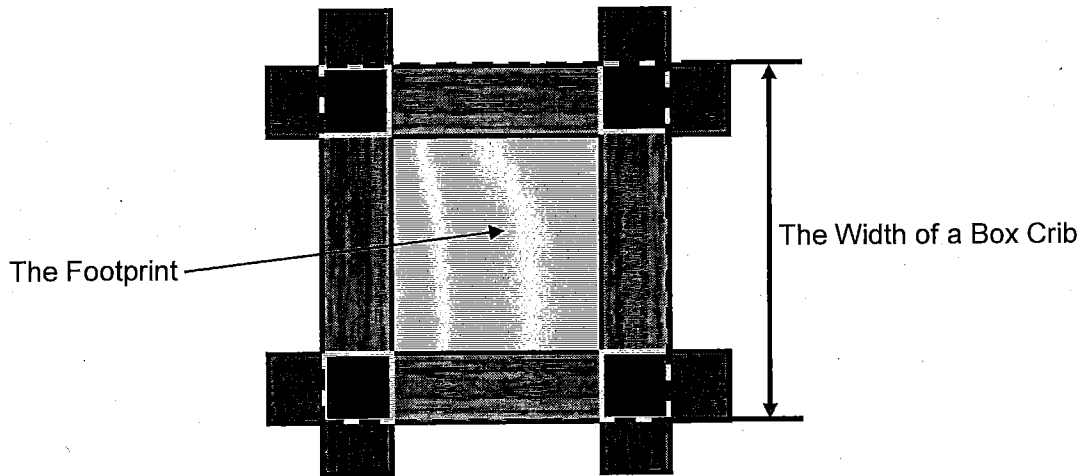


Triangular

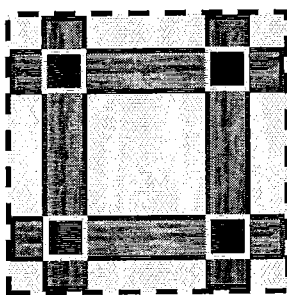


Parallelogram

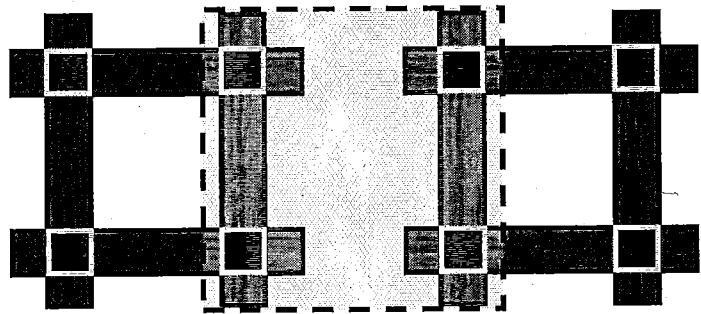
As mentioned previously, when referencing the height to width ratio of a box crib it is important to note that the width is NOT the length of the piece of cribbing. Instead, it is the distance between outer edges of the points of contact. The area around the points of contact is sometimes referred to as the box crib's "footprint". The larger the footprint, the more lateral stability in the crib.



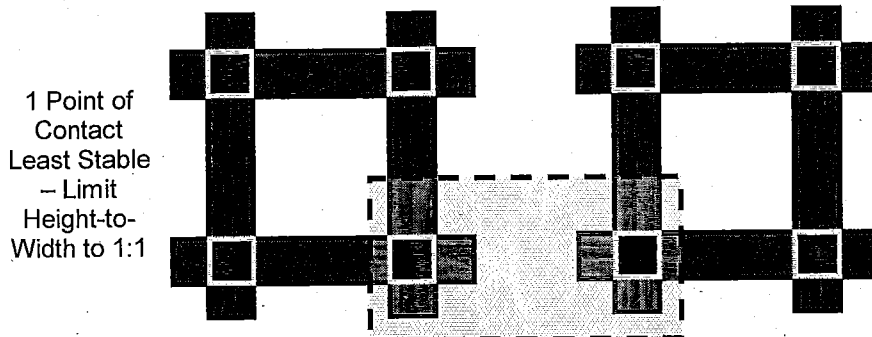
As we calculated earlier each point of contact can carry a specific load. The more points of contact under load, the more stable the box crib. As the number of points of contact under load decrease, the lateral stability of the crib decreases. This decrease in lateral stability results in a decreased safe working height of the box crib.



4 Points of  
Contact  
Most Stable –  
Height-to-  
Width can be  
3:1



2 Points of  
Contact  
Less Stable –  
Limit Height-  
to-Width to  
1.5:1

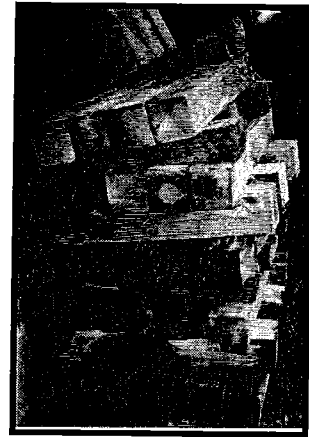


1 Point of  
Contact  
Least Stable  
– Limit  
Height-to-  
Width to 1:1

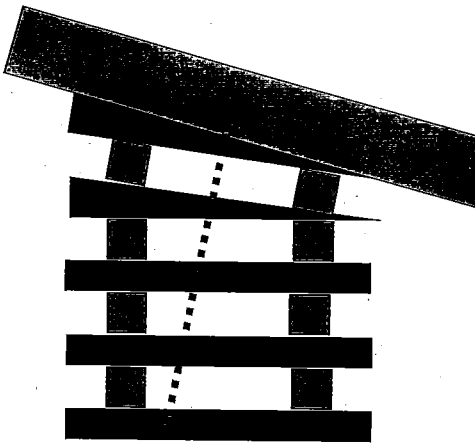
## Slopped Box Crib

Box cribs can be "perfect" vertical structures or they can be built with a slight lean or incline. The incline is engineered into the crib to provide a solid base layer to spread the load and a top layer that offers as much surface to wood contact as possible.

During construction of a slopped box crib, layers of cribbing are replaced with shims. The shims must be the same dimensional size as the cribbing (i.e. 4x4 cribbing and 4x4 shims). The shims are placed in a manner to create an angle that closely matches that of the load being supported. A row/layer of regular cribbing is placed perpendicular to the row/layer of shims.

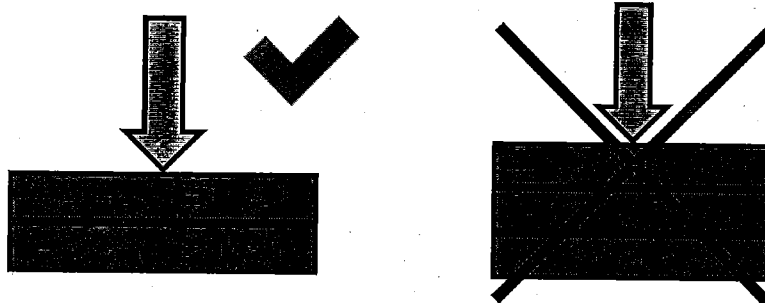


The design criteria of the slopped box crib requires the load path to be contained within the footprint of the crib.



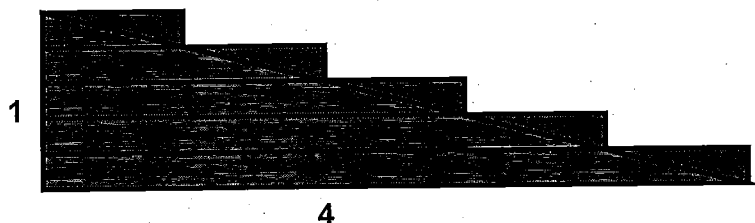
## Other Considerations

As mentioned several times in this module, stability is a very important aspect of stabilization. When working with cribbing, it is sometimes advantageous to stack multiple pieces of cribbing parallel to one another. Due to lateral instability, it is strongly recommended that no more than two pieces of cribbing be stacked in the same direction. Exceeding this number increases the risk of the cribbing layers rolling off and falling.



## Step Chocks

Step chocks are portable, pre-fabricated versions of cribbing. The most common step chock is comprised of 5 pieces of wood, each 6" shorter than the one below it. The base of the step chock is 30" long and the last "step" is 6" long. For best load stabilization the length to height ratio should be 4:1. If the 4:1 ratio is utilized, the step chock acts as an incline plane redirecting the force to the ground.

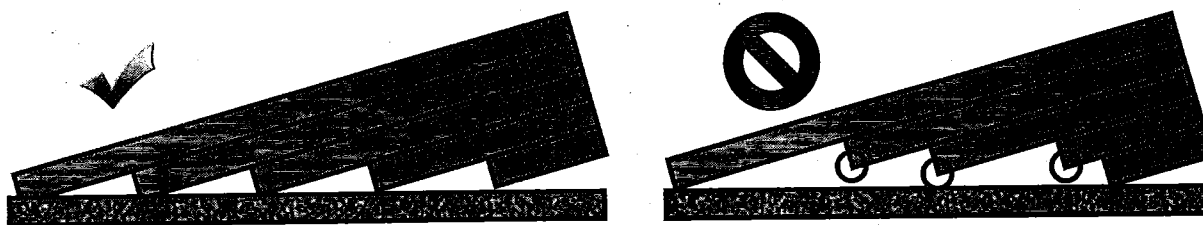


The chock is most often made with 2x6 lumber, although some departments use a 2x6 base with steps made from 2x4's.

The primary goal in using steps chocks is to install the chock so that it does not interfere with patient packaging, does not prevent the opening of car doors and must importantly, does not become a trip hazard. Another consideration in the placement of step chocks is the potential to push a dash or the cutting of a rocker panel.

### Place the step chock upright or inverted?

Both orientations of the step chock are acceptable under the right circumstances. If the chock does not interfere with the scene operations and does not pose a trip hazard, inverted is acceptable. One caveat to this statement is the use of step chocks with 2x6 bases and 2x4 steps. When inverted, these chocks are not adhering to the double funnel principle. The 2x6, now on top, is wider than the 2x4 base which causes the step chock to be unstable. Another situation where inverting would not be appropriate would be when all five corners of the steps are not in contact with the ground or stabilizing surface. Poorly constructed step chocks that do not have uniform step dimensions can create this issue. To properly distribute the load across the ground, all five corners must make contact.

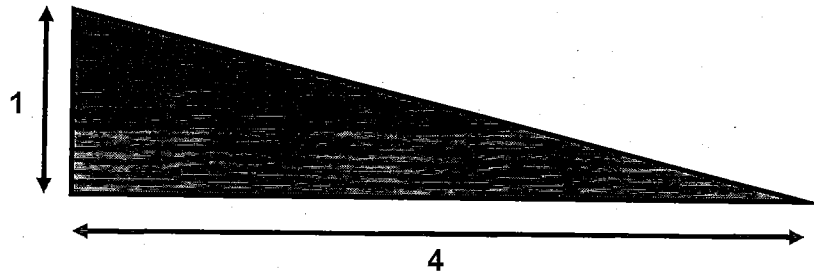


Step chocks are carried on nearly every frontline piece of heavy apparatus. They are a useful tool for stabilization. However, it's important to remember that they are not the ONLY tool – there are many situations where step chocks cannot provide adequate stabilization and will not work.

## Shims and Wedge Sets

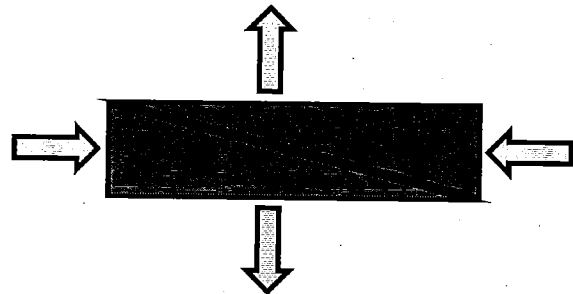
### Shims

A shim is a piece of dimensional lumber that was cut diagonally to form a right triangle. This triangle creates an **inclined plane** – one of the six classical simple machines. Shims are used to fill voids when cribbing, change angles (e.g. sloped box cribs), and when acting as a **wedge** (another type of simple machine), to impart force upon an object. Similar to step chocks, shims are preferably cut with a 4:1 pitch.



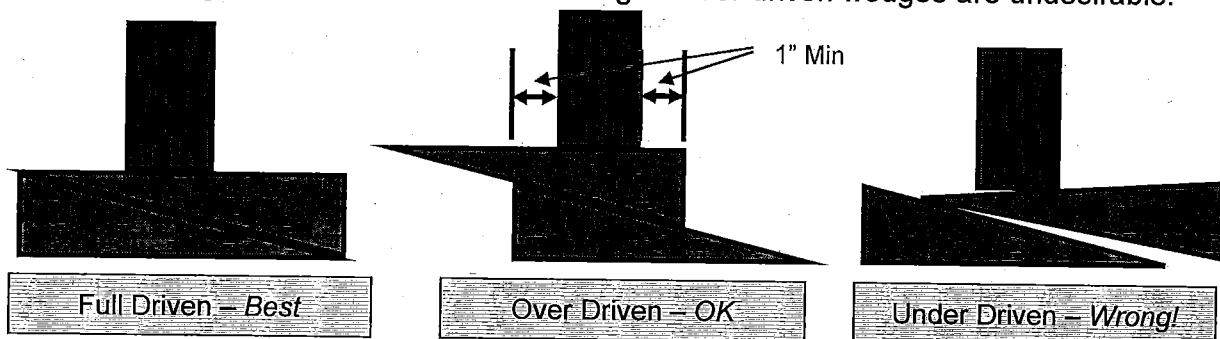
### Wedge Set

A wedge set (sometimes simply called a "wedge") is a pair of shims cut from the same piece of material. Since the cut is identical on both shims, the two fit together as a perfect married pair. Maintaining maximum surface contact in a wedge set is important. So it is best to keep married pairs of shims together and place the cut sides together.



As mentioned above, a wedge is a form of a simple machine. As such, it uses the inclined plane shape to create mechanical advantage. When a wedge set is driven together, it can generate as much as 500-700 lbs. of force to lift or move an object. It is important to remember this because sometimes this force and corresponding movement is desired and sometimes it is not.

When marrying a wedge set together, it is important to understand the terms "Full Driven", "Under Driven", and "Over Driven". Fully driven wedges are best. Over driven wedges are ok as long as there is sufficient overhang. Under driven wedges are undesirable.



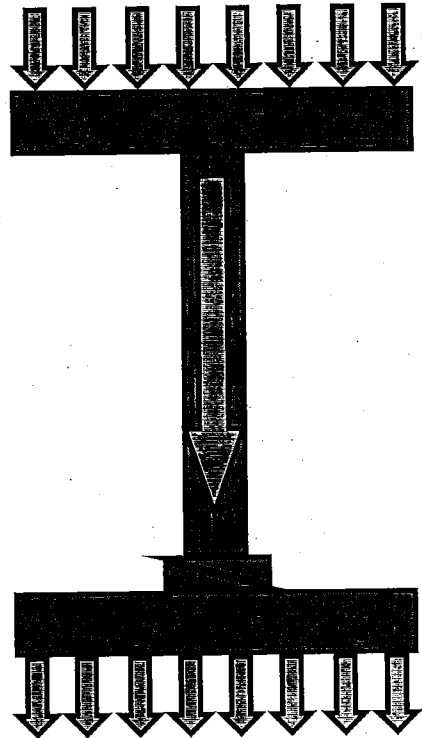
## Vertical Post Shoring

Often times, vertical post shores are utilized in addition to or in lieu of cribbing. Vertical shores tend to take up less space than a box crib and are able to provide stabilization at greater heights.

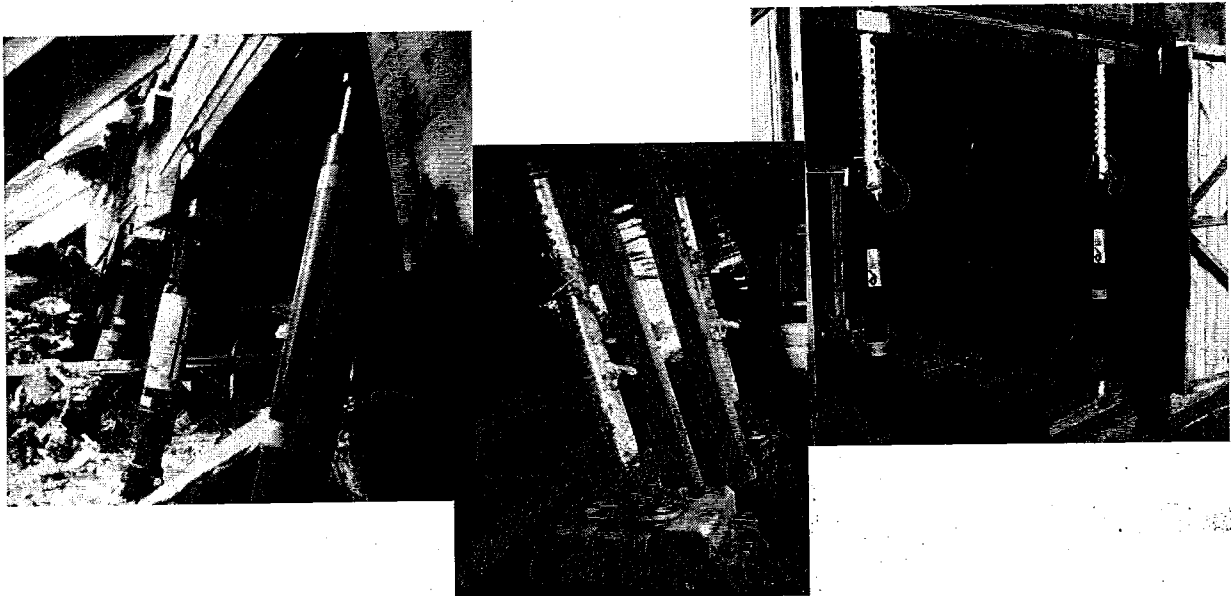
Wooden post shores are constructed of a header, post, and footer. These work together to achieve the double funnel principle in stabilizing the load. All components of the vertical shore should be connected together to form a complete system. The post height is adjusted using a wedge set (preferably a 2x4 wedge set).

The length of a post in a wooden shore is limited to prevent buckling. For longer post lengths, lateral bracing must be incorporated. The design strengths of wooden post shores are as follows:

Post Size	Design Strength	Length
4x4	8,000 lbs.	Up to 8 feet
6x6	20,000 lbs.	Up to 12 feet



In addition to wood, several manufacturers produce mechanical struts that serve the same purpose as a wooden post shore. These struts are usually constructed of aluminum and offer quick and easy height adjustment. Just like their wood counterparts, mechanical shores lose strength as they become longer due to buckling failure. Always adhere to manufacturer's working load limits when using mechanical struts/shoring.

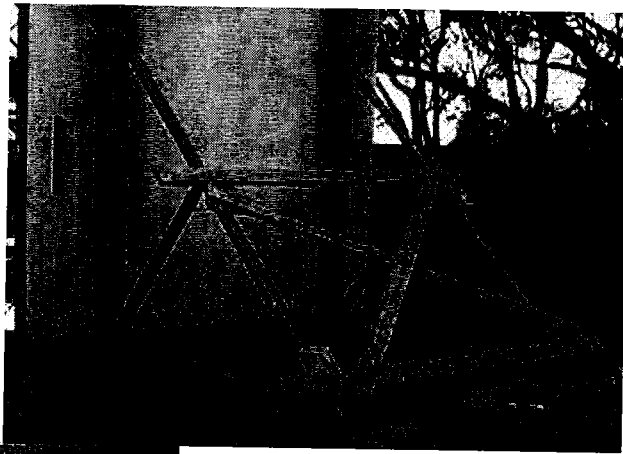


## Raker Shoring

Up to this point, this module has discussed stabilizing an object vertically. There are also times that a load must be stabilized for horizontal movement. This is the job of a raker shore.

Rakers can be constructed of wood or mechanical struts. Elaborate raker shore construction is usually reserved to structural collapse. However, day-to-day rescue squad operations can still involve the use of rakers. One such example is the vehicle tie-back.

Numerous different types of mechanical struts are used within the fire and rescue service. It is imperative that personnel have mastery of the construction, setup, use, and capacities of the specific struts carried on their particular apparatus.



# Power Tools – Saws and Torches

## Introduction

Rescue squads carry a wide variety of cutting tools designed for many different operations. Personnel assigned to a rescue squad or extrication truck may be required to perform tasks ranging from cutting ventilation holes in a roof to removing doors from a car to cutting a hole in a concrete floor. Hydraulic and pneumatic cutting tools are discussed in other modules. This module will focus on saws and torches that are commonly found of rescue squads and extrication trucks.

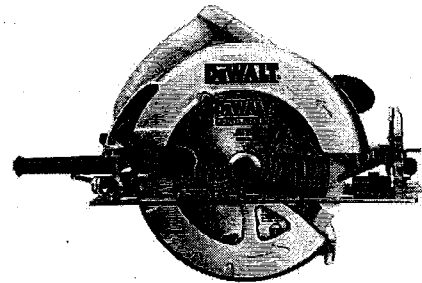
## Saws

Portable saws are an excellent resource on both the fire ground and rescue scene. Rescue squads and extrication trucks carry both gasoline-powered saws and electric/battery-powered saws.

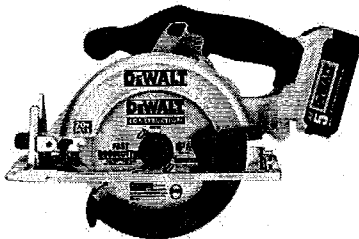
### Electric-Powered Saws

#### Circular Saws

Circular saws are often associated with construction and carpentry work - not rescue. However, they are a necessity on technical rescue incidents such as structural collapse or trench rescue.

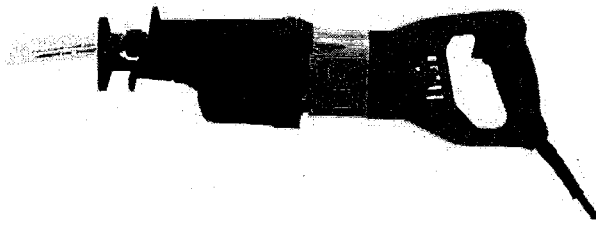


Circular saws can be both electric and battery powered. Electric saws require a 120V power supply and typically operate at 15 amps. Therefore, a sufficient power source must be available to use these saws (smaller 1000W portable generators will not work). For remote operations, cordless saws offer a good alternative. These saws use rechargeable batteries. Manufacturers are constantly improving their battery technology. Currently, lithium-ion batteries used for cordless circular saws range from 18V up to 36V.



The standard blade size for electric circular saws is 7<sup>1</sup>/<sub>4</sub>". Larger saws with 10<sup>1</sup>/<sub>4</sub>" blades also exist and are used for cutting 4x4 lumber. Cordless saw blades use smaller 6<sup>1</sup>/<sub>2</sub>" blades.

## Reciprocating Saws



Reciprocating saws are used for demolition work and in situations where the precision of a circular saw are not needed. Unlike circular saws that use the rotary motion, reciprocating saws use a "push and pull" reciprocating motion of the saw blade. Reciprocating saws are often called

"Sawzalls". Sawzall® is actually the brand name of reciprocating saws manufactured by Milwaukee Electric Tool Corporation.

Like circular saws, reciprocating saws can be electric or cordless. Electric varieties operate on 120V from 10 up to 15 amps. Cordless reciprocating saws use nickel-cadmium (NiCad) or lithium-ion (Li-Ion) batteries similar to those used with cordless circular saws.



Reciprocating saws can be used to cut many different materials. The key to cutting ability and performance is choosing the proper blade. Some saw blades are made specifically for cutting wood or metal. Others blades are general purpose or demolition blades designed to cut wood, metal and plastic. Specialty blades, such as those with tungsten carbide teeth, are also available. Lengths can range from 4" to as long as 12".



## Gasoline-Powered Saws

Gasoline power saws use a small internal combustion engine to provide power. The engines are 2-stroke (or 2-cycle), meaning they only have a compression and combustion stroke. 4-stroke engines, such as those found in most automobiles, have separate intake, compression, combustion and exhaust strokes.

There are both advantages and disadvantages of 2-stroke engines vs 4-stroke engines:

### Advantages of 2-Stroke

- Do not have intake/exhaust valves, which simplifies their construction and lowers their weight
- Fire once every revolution, which provides a significant power boost
- Can operate in any orientation
- Good power-to-weight ratio

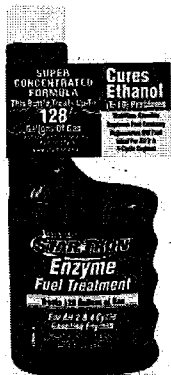
### Disadvantages of 2-Stroke

- Lack a dedicated lubrication system like 4-stroke engines, which means internal components wear faster
- Lack of dedicated lubrication system means that 2-stroke oil must be added to gasoline
- Very inefficient (higher fuel consumption)
- Produce a lot of pollution – both from oil burning with the gasoline and unburnt fuel/air mixtures escaping through the exhaust port



The use of mix-fuel is how many people identify a 2-stroke engine. To create the mixture, 2-stroke oil is added to the gasoline prior to fueling the saw. A 50:1 fuel/oil ratio (2.6 U.S. fluid ounces of oil per 1 gallon of gasoline) is common for many saws. However, it is best to always follow the owner's manual and manufacturer's

recommendations. For instance, Cutters Edge recommends a 100:1 fuel/oil ratio when using their brand of oil, but 50:1 when using other petroleum-based oils.



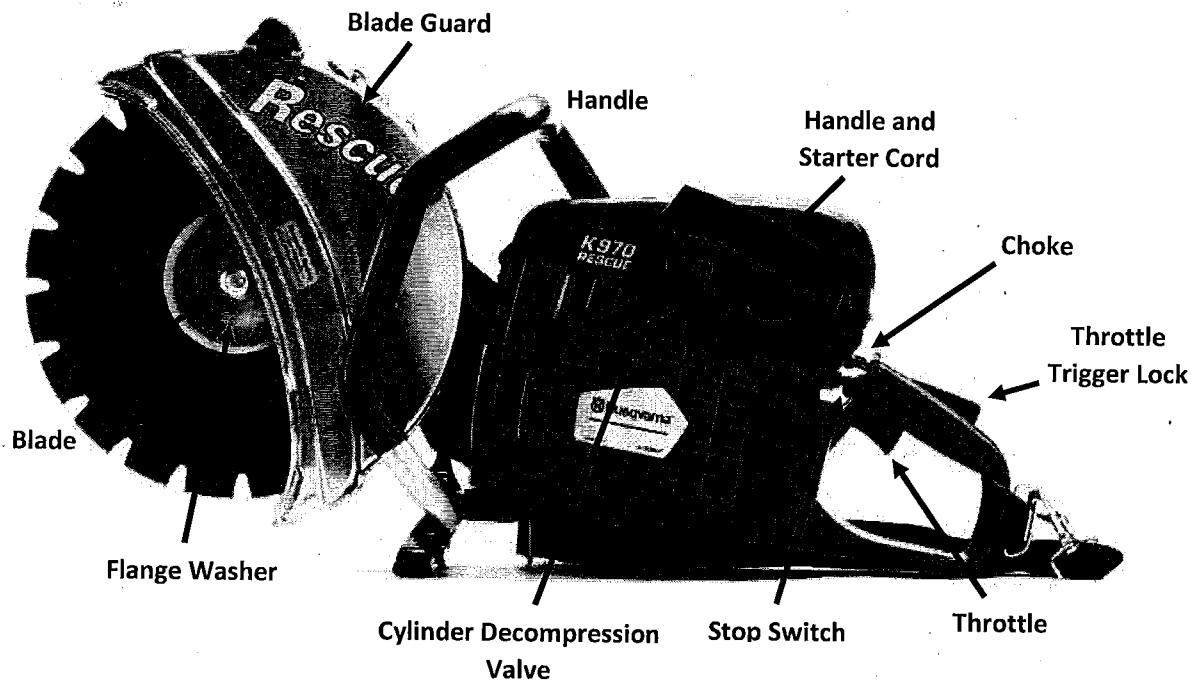
One fairly recent development with 2-stroke engines is the increase in engine problems associated with the use of ethanol in gasoline. Alcohol is said to cause deposits and corrosion and affect the ignition timing of the fuel. The ill effects of E10 gasoline can be combated in a couple different ways: One is to use pre-mixed fuels that do not contain the high levels of alcohol. However, these can be expensive. The other alternative is to use fuel additives such as Marine Sta-Bil or Star-Tron. These stabilizers help prevent the damaging effects of ethanol.



## Types of Saws

### Rotary Cut-Off Saws

Rotary cut-off saws are larger, more powerful versions of electric-powered circular saws. They are predominantly used for cutting metal, concrete and stone. The Husqvarna K970 and K760 rescue saws are two common types of rotary cut-off saws. (Partner® rotary saws are still carried on some apparatus. In 2006, the Partner® brand became part of Husqvarna.) Some of the parts of the Husqvarna rotary saws are shown below:



### Blades

#### Abrasive Blades

Composite abrasive blades are composed of grit bonded by an organic binding agent. Some of these blades are reinforced with a fabric or fiber base to prevent complete blade failure and breakage during operation should the blade sustain a crack or damage. Abrasive blades are designed for specific applications. Their cutting performance is determined by the type and size of the abrasive material used and the type and hardness of the binding agent. Some examples include:

- Metal
- Concrete/masonry
- Asphalt
- Rail

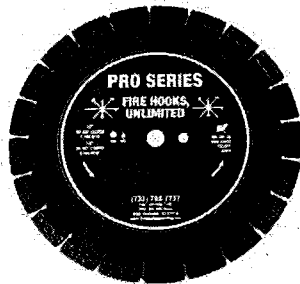


There are many different manufacturers of abrasive blades. It is imperative that the blade and saw manufacturer's recommendations are followed during their use. Some factors to consider include:

- Adhere to minimum and maximum blade diameters
  - Each saw has a maximum allowable blade diameter
  - Abrasive blades are consumed as they are used. Once the blade wears down to the minimum allowable diameter, it should be replaced
- Use the correct type of blade for the material being cut
- Compare the speed rating of the blade to that of the saw. Do not use a blade with a rating lower than that of the saw.
- Be cautious with water. While there are some abrasive blades designed to be used with water, there are many that are not.



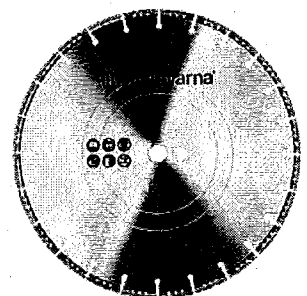
### Diamond Blades



Diamond blades are constructed of a steel wheel with cutting segments containing industrial diamonds. When used properly, they are more durable and will last longer than abrasive blades. Like abrasive blades, diamond blades are designed for specific materials and cutting applications. Some blades are designed only for concrete, masonry and stone. Other diamond blades, specifically those marketed for the fire/rescue service, are designed to cut a wide variety of materials including reinforced concrete, cast iron, rail, steel, brick, rubber, wood, metal, PVC pipe, rebar and plexi-glass.

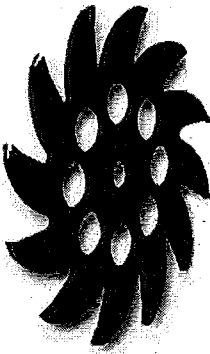
The blade manufacturer's recommendations must always be followed. When using diamond blades, the operator should also check the following:

- The blade must be mounted to the saw so that it rotates in the proper direction (if applicable)
- The diamond cutting tips can become dull and/or wear when cutting hard surfaces. A sharp blade should always be used.
- Determine if the blade is designed for dry or wet cutting. If it can be used for dry cutting, it may be necessary to regularly pull the blade away from the cutting surface to prevent overheating. If it is designed for wet cutting, water must be used to prevent the blade from overheating.



### Toothed Blades

Nearly all manufacturers of gasoline-powered rotary cut-off saws specify that toothed blades should only be used for specialized situations (i.e. rescue work) by trained professionals. Therefore, toothed rotary blades are not common. One manufacturer of a toothed blade specifically designed for the fire service is Warthog Products, Ltd. They



manufacture the Warthog™ blade that is outfitted on many of the Husqvarna/Partner saws carried on rescue squads and truck companies. The Warthog™ blade is constructed with carbide tips and designed for cutting through floors, walls and roofs. The thick blade design provides strength and durability. However, special mounting procedures exist to ensure that the blade remains properly attached to the saw arbor. The Warthog™ blade, like other specialized tools, can prove beneficial after proper training on its use. The manufacturer's operating guidelines should always be followed.

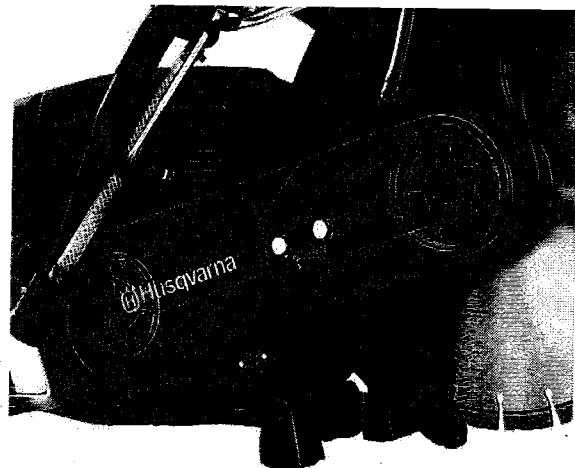
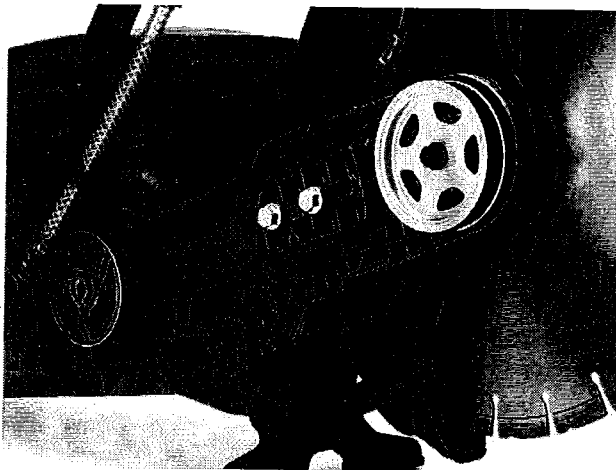
### Blade Inspection and Maintenance

Regardless of the type of blade being used on a rotary cut-off saw, there are some basic inspection and use guidelines that should always be followed:

- Check for any damage to the blade (chips, cracks, broken teeth, etc.) and remove from service if necessary.
- Ensure that the blade is securely fastened to the saw and does not vibrate or wobble when used.
- Store saw blades in a clean, dry environment, away from corrosive fluids and fuels.

### Rotary Saw Maintenance

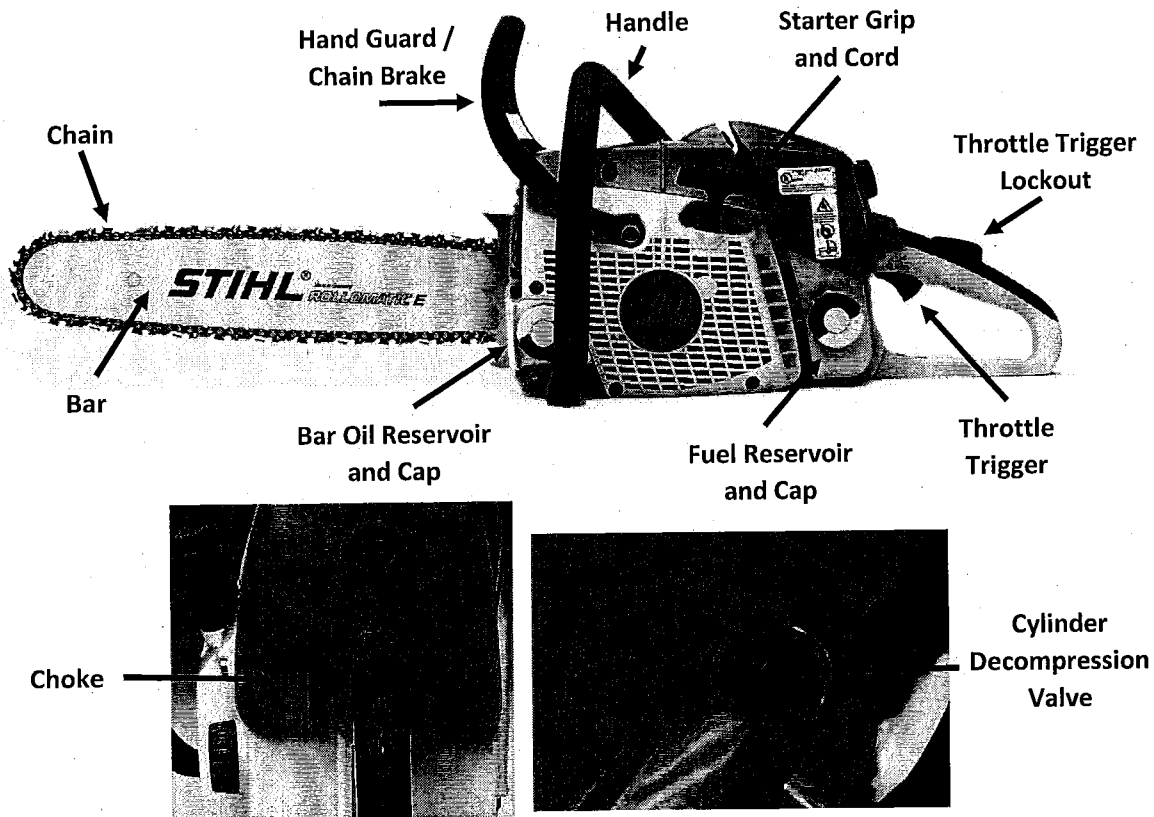
Rotary cut-off saws are belt driven. The drive belt tension should be periodically checked and adjusted if needed. Each saw manufacturer will specify the exact procedure for adjusting belt tension and provide guidelines for belt replacement.



Other maintenance procedures include general cleaning, checking that the starter cord properly recoils and ensuring that the saw is full of fuel with the fuel cap secured. More detailed maintenance and use guidelines will be covered in the manufacturer's user manual.

## Chain Saws

There are a variety of chain saws used in the fire service. Some are similar to those used by the average homeowner while others are more robust, like those used by farm and tree work professionals. There are also fire/rescue specific chainsaws used for ventilation on a fire ground. While different saws have unique features for given applications, many of them share common components. Some of those components are shown below:



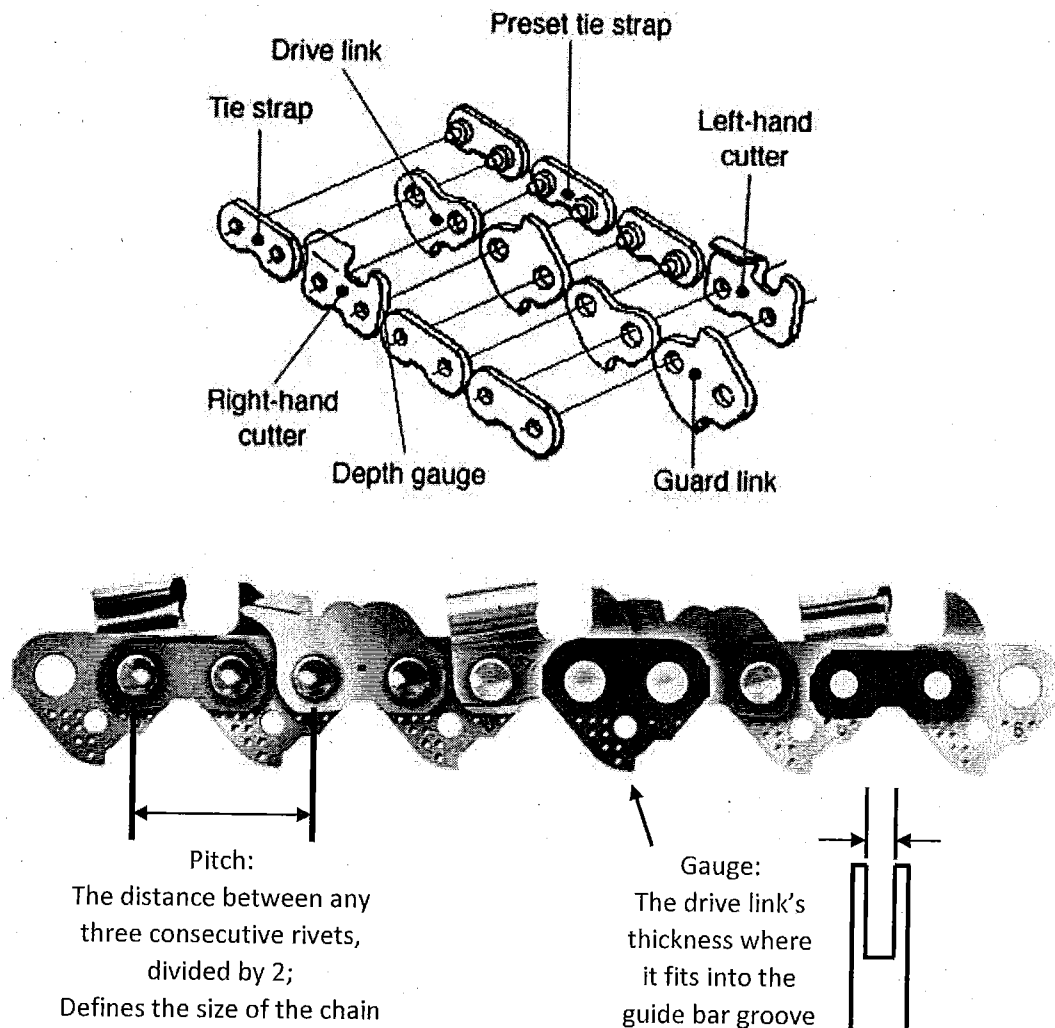
## Bars and Chains

Chainsaw bars come in a variety of lengths. Some can be as short as 10 inches while others used for severe duty felling operations can exceed 40 inches in length. Most manufacturers recommend a range of bar lengths based on the intended use.



There is also a wide variety of options for chainsaw chain. Manufacturers design chains for specific cutting applications. A chain used by a professional logging company will be different than one used by the average homeowner. Likewise, there are several varieties of chains designed specifically for the fire service.

To help differentiate between different types of chains, it is beneficial to know some of the basic components and terminology:

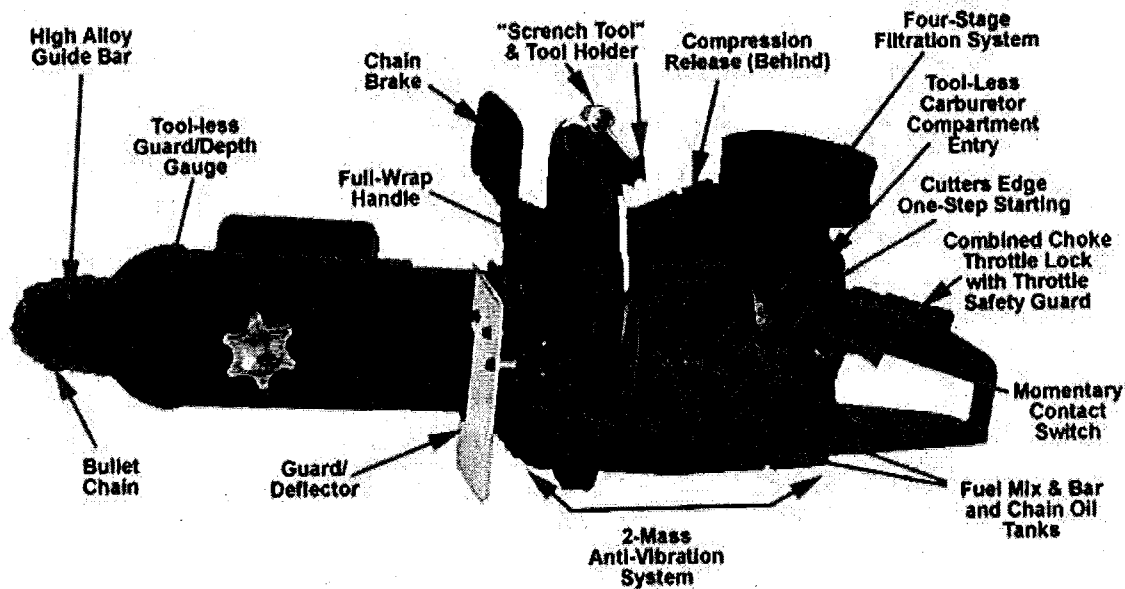


The length of the chain is determined by counting the number of drive links. The drive link count, pitch, and gauge must all be matched with the specific guide bar on the chainsaw.

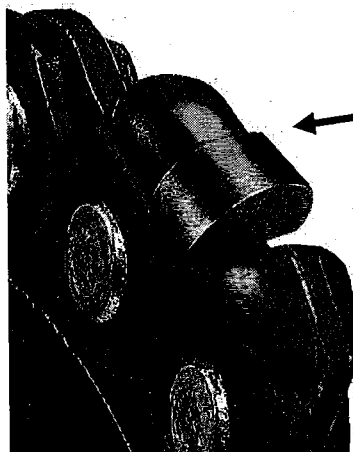
## Fire/Rescue Chainsaws



One popular manufacturer of chainsaws designed specifically for the fire service is Cutters Edge®. The Oregon-based company manufactures several different saw products and accessories. The Multi-Cut® Fire Rescue Saw is designed for fire department ventilation operations and is carried on nearly all truck companies and rescue squads in the Department.



In addition to some of the unique saw features, the chain itself was designed by Cutters Edge® with the fire service in mind. The Cutters Edge Bullet® Chain is a carbide-tipped chainsaw chain designed specifically for the variety of materials that firefighters may encounter during fire/rescue operations. These include common building materials such as roofing nails, joist hangers, nailing plates, flashing, light gauge sheet metal and even some lightweight concrete. The Bullet® Chain is also capable of cutting automotive sheet metal and glass, hurricane glass, bulletproof glass, plastics, fiberglass, and other composite materials.



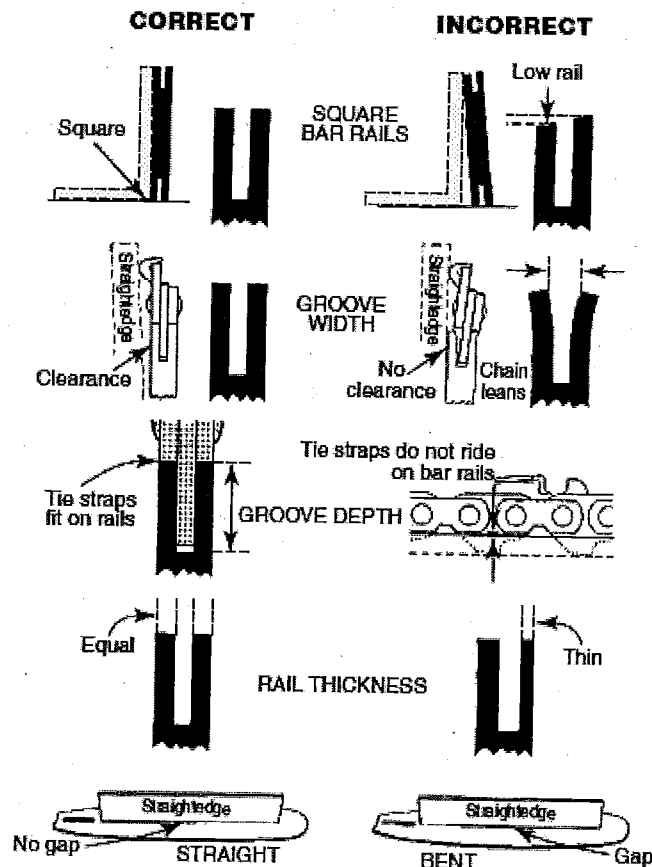
**Cutter:**  
Solid piece cutter without bends or ground-out areas with a sintered carbide insert that creates a larger cutting surface, designed specifically for fire department use

**Bullet® Depth Gauge:**  
Shaped like the nose of a bullet and designed to protect the carbide insert from impact during cutting

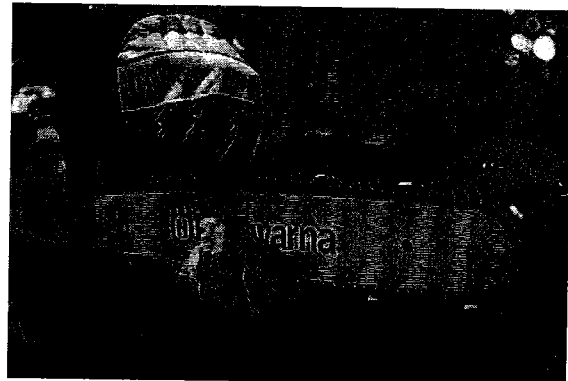
## Chain and Bar Maintenance and Inspection

Proper chain maintenance is critical for efficient and safe cutting operations. There are several areas that should be the focus of daily inspections:

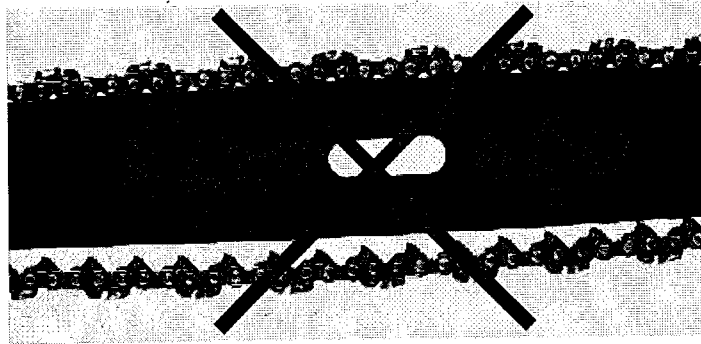
- **Guide Bar Condition:** The guide bar should be checked for damage, uneven or abnormal wear to the rails, and should not be bent



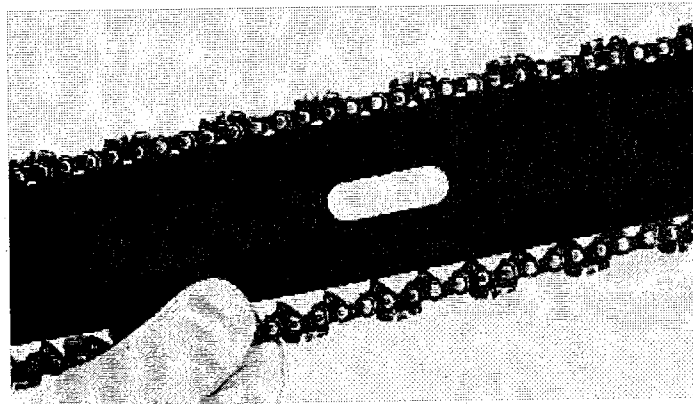
- **Chain Tension:** Improper chain tension can damage both the bar and the chain. Tension should be checked on a cool bar and chain. Heat from saw use causes the chain to expand. If the chain tension is set while the chain is still hot, the chain will be too tight when it cools. Prior to checking chain tension, ensure the saw is OFF and wear protective gloves. Pull the chain along the top of the bar several times from engine to tip. The chain should feel snug, but still move freely. If the chain catches or requires excessive force to move, it is too tight.



At proper tension, the chain should be in full contact with the bottom of the bar.



When pulling down on the chain at the midpoint along the bottom rails, the drive links on the chain should just clear the rails and snap back into place when the chain is released.



If the chain needs to be tensioned, the procedure outlined in the chainsaw's operating manual should be followed. Different chainsaws may have different designs so the tensioning procedure can differ from one manufacturer to another.

- **Chain Sharpness:** If the cutting tips on the chain are not sharp, the saw will not cut well, causing fatigue to the operator and increased wear and tear on the chain and bar. Chains can be sharpened, although this is typically not done at the station level and should only be performed by a trained professional. The cutting performance of a saw during use is one of the best indicators of chain sharpness. If the saw does not appear to be cutting well, it could be a result of a dull chain.
  - **Cutter's Edge Bullet® Chain:** This chain is designed to allow chips of carbide to break away during normal use. If six or more cutters have 50% or more of the carbide missing, the chain should be repaired and sharpened. Also, if 3 or more cutters in a row or 6 or more total on the entire chain are broken or seriously damaged, the chain should be repaired.

- **Proper Lubrication:** Chainsaws have a chain oiler to minimize wear and tear on the bar and the chain. Ensure that the chain oil reservoir is properly filled with the manufacturer-recommended bar oil. During operation, the chain should always throw off a small amount of oil.



- **General Cleaning:** Buildup of sawdust and debris can inhibit saw performance and increase wear and tear. The saw should be wiped down and cleaned as needed. It may be necessary to remove the clutch cover and clean sawdust and oil buildup found behind it. Ensure that the port for the bar oil feed is free of debris. Consult the chainsaw owner's manual for disassembly and reassembly instructions.



## Torches

Torches offer an alternative to saws for metal cutting operations. While their setup and use may not be as quick and easy as a saw, there are certain applications where they may be the best or only option. Similar to welding, torch work is an art that requires proper training and a lot of practice. The amount of time spent training with torches will directly impact performance on an actual incident.



While there are many different types of cutting torches used in both industrial and rescue settings, this module will discuss two types that are carried on rescue squads in Montgomery County.

### Oxy/Fuel Torches

Oxygen/fuel (oxy/fuel) torches cut ferrous metals through the process of heating the metal with an oxy/fuel flame and then melting it away with a powerful jet of oxygen. The oxygen/fuel gas flame preheats steel to its ignition temperature. Once this temperature is reached, a stream of high-pressure oxygen is directed onto the steel. The oxygen reacts with iron in the steel to form iron oxide. This oxidation reaction is exothermic, which produces additional heat to help melt any remaining steel. Molten iron oxide, known as slag, is blown out of the cut with the high flow of oxygen.

A variety of fuels can be used with oxy/fuel torches. Each has different chemical (and therefore different cutting) properties with unique advantages and disadvantages. Some common fuel gases are:

- Acetylene: Produces the highest flame temperature of all common fuel gases, making it one of the most popular fuels
  - LEL: 2.5%
  - UEL: 100%
- Propane: Lower flame temperature than acetylene, but has a greater total heat of combustion
  - LEL: 2.1%
  - UEL: 9.5%
- Methyl acetylene-propadiene (MAPP): Lower flame temperature than acetylene, but is less combustible and can be used at higher pressures
  - LEL: 3.4%
  - UEL: 10.8%

In addition to the above gases, another fuel source used with some cutting torches is gasoline:

- Gasoline: Class IB flammable liquid
  - Flash Point: -45°F

- LEL: 1.4%
- UEL: 7.6%

\*\*Chemical properties obtained from NIOSH Pocket Guide to Chemical Hazards

As indicated previously, acetylene is one of the most popular and widely-used fuel gases for cutting torches. It has the distinct advantage of being able to both weld and cut. The major disadvantage to oxy/acetylene torches is the acetylene gas itself.

Acetylene presents the following disadvantages:

- It has a tremendously flammable range (2.5% - 81%)
- It is extremely hazardous at pressures exceeding 15 psi
- Acetylene molecules ( $C_2H_2$ ) are held together with a triple carbon bond. While this bond is useful in that it stores a significant amount of energy that can be released during combustion, it is also highly unstable. This makes acetylene gas sensitive to conditions of excess pressure and temperature, static electricity, or mechanical shock.
- Due to its unstable nature, acetylene must be stored under special conditions. The acetylene gas is dissolved in liquid acetone and stored in cylinders containing a porous filler material. The acetylene cylinders must be stored in an upright configuration at all times to prevent loss of the acetone and an increase in the instability of the acetylene.

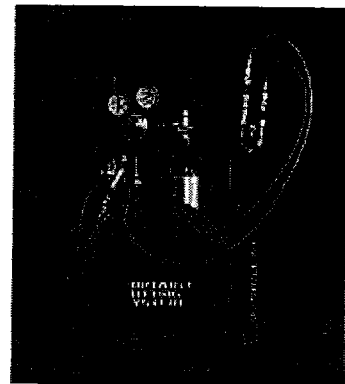
\*\*Information from U.S. Dept. of Labor Mine Safety and Health Administration (MSHA)

The unstable properties of acetylene make it a less than desirable fuel of choice for fire/rescue applications where torches are stored and transported on apparatus, not in relatively stable industrial shops.

### Petrogen Torch

The Petrogen torch is an oxygen/gasoline torch manufactured by Petrogen, Inc., based out of Colorado Springs, CO. The Petrogen torch has some of the following advantages over acetylene for rescue work:

- Gasoline is much more stable than acetylene (flammable range is only 1.4% to 7.6%)
- The gasoline remains in its liquid form until it reaches the torch tip
- Gasoline is readily available (carried on all truck companies and rescue squads) and does not need special cylinders for storage



Unlike oxy/acetylene torches that can be used for welding and cutting, the Petrogen torch is only used to cut. However, it performs this task very well.

This unit comes with a small fuel can and a small oxygen cylinder, a backpack style carrier and a 20" torch wand with dual 20' hoses. This system is designed for mild cutting limited to 15 to 20 minutes. If the product that you are cutting is thicker than 1" than this cutting system will only last 5 min. With the Fire and Rescue resources' are so abundant an M bottle would be the preferred oxygen supply for this cutting system. The following is a step by step process for using the Petrogen torch, however personnel must practice with this equipment to be proficient.

To Light & Adjust
1. Select tip and set oxygen tank pressure according to the Cutting Tip & Pressure Chart. (Chart also found on the PETROGEN tank.)
2. Pump gasoline tank pressure to 20 psi.
3. Open gasoline tank valve slowly at first so that the fast-flow check valve does not seat. Then open fully.
4. Purge oxygen hose for at least 5 seconds by depressing the cutting lever.
5. Open torch oxygen valve about 1/2 turn.
6. Open torch gasoline valve until fine mist appears. No drops.
7. Purge oxygen line again.
8. Strike a spark close to the tip slightly to one side.
9. Press tip to steel for about 4 seconds to warm it.
10. Adjust the flame by opening and closing gasoline valve until steel reacts with the brightest orange and red color

To Shut Down
1. Shut torch gasoline valve first.
2. Then close torch oxygen valve.
3. Check to make sure tank filler cap and tank shut-off valves are closed.

There are many tips for the torch wand that offer different cutting capacities. The chart below identifies the tip sizes available in the tool kit with the unit and corresponding cutting capabilities.

**CUTTING TIP SELECTION CHART**

Tip No.	Thickness of Steel
0	< 1/4"
81	1/4" to 1"
83	2" to 4"

Other tip sizes are commercially available to cut steel materials up to 14" thick.

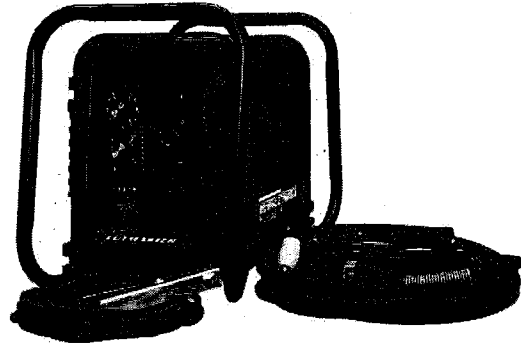
### Safety

During cutting operations, monitor the gasoline tank pressure and ensure it remains above 10 psi. When the gasoline tank pressure reaches 10 psi, re-pressurize the tank to 20 psi. The fast-flow check valve needs 10 psi to operate properly. When operating, keep the gasoline valve fully open to ensure proper operation of the fast-flow check

valve. The oxy-gasoline torch can reach temperatures of 5,200°F, therefore precautions must be taken against burns to personnel as well as ignition of nearby combustibles.

### Plasma Arc Torch

The cutting action of a plasma arc torch is the powerful constricted electric arc in combination with a high velocity gas. The electric arc actually blasts the metal into fine particles. Cutmaster 82 from Thermal Dynamics is the plasma cutter carried by MCFRS Rescue Squads.



The Cutmaster 82 requires 220V AC current to operate and an air supply of approximately 100 psi at the unit. These units are portable, however usually limited to the reach of the apparatus electric cord reel supplying the power. The compressed air may be obtained from the apparatus mounted reel or an SCBA cylinder with a regulator.

### Safety

The plasma arc process uses and produces high voltage electrical energy. This electric energy can cause severe or fatal shock to the operator or others in the workplace.

In addition to high voltage electricity, the plasma arc process produces very bright ultra violet and infra red light. These arc rays will damage your eyes and burn your skin if you are not properly protected.

- To protect your eyes, always wear a welding helmet or shield. Use the shade of lens as suggested in the following per ANSI/ASC Z49.1:

Arc Current	Minimum Protective Shade No.	Suggested Shade No.
<300	8	9
300-400	9	12
400-800	10	14

- In addition to the helmet or shield, always wear safety glasses with side shields, goggles or other protective eye wear.
- Wear welding gloves and suitable clothing to protect your skin from the arc rays and sparks.
- Keep helmet and safety glasses in good condition. Replace lenses when cracked, chipped or dirty.
- Protect others in the work area from the arc rays. Use screens or shields.

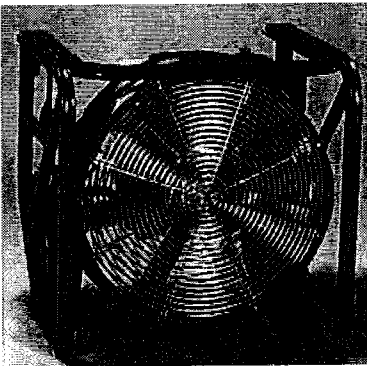
## Portable Fans

Portable fans provide the fire service a vehicle for achieving one of several critical elements of any firefighting effort: timely and effective ventilation of an affected structure. Whether carried out as part of a well-coordinated fire attack, or during overhaul operations, the ability to rapidly remove smoke and heat from an structure is paramount to any successful firefighting operation. Observable reductions in property damage, more tenable firefighting conditions, and overall improvements in firefighter health and safety are tangible benefits which occur with the use of portable ventilation fans.

Various manufacturers produce fire department ventilation fans. As such, several varieties of fan models and styles exist. Fan sizes may range from small (often electric or water-powered) to larger gasoline-powered blowers. In some instances, personnel may have the availability of much larger, trailer-mounted exhaust fans, similar to those in use by airboats. Regardless, each fan has specific applications and limitations. As such, the Rescue Squad driver/operator must be knowledgeable of the various types and specific operating characteristics of all fans carried on his/her unit.

### Power Source(s)

The type of fan employed on the fireground is largely driven by the nature and availability of specific power sources. Until the early 1990's, the fire service utilized electric "smoke ejectors" for all ventilation applications. This resulted from the fact gasoline-powered fans had yet to be introduced to the fire service.



The introduction of gasoline-powered portable fans drastically altered the "standard" of fireground ventilation. These fans consist of a small, frame-mounted, 4-cycle motor which is connected to a multiple-prop blade. Gasoline-powered fans offer the versatility of compactness and mobility, while simultaneously producing enormous volumes of air.

One of the major drawbacks of the gasoline powered portable fans is the large amount of carbon monoxide produced by the motor that is then drawn into the fan and forced into the building or area being ventilated.

### Size/Capabilities

The specifics of fire service ventilation fans vary greatly from manufacturer to manufacturer. Detailed information regarding a fan's specifications can be found within the manufacturer's instruction manual or on a data plate on the fan.

## Maintenance

Fans require considerable maintenance and cleaning in order to maintain operational readiness. Important factors to consider include:

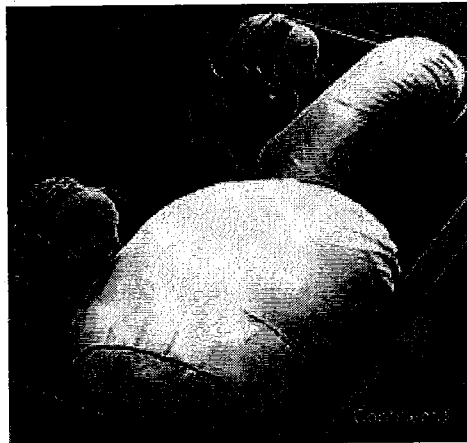
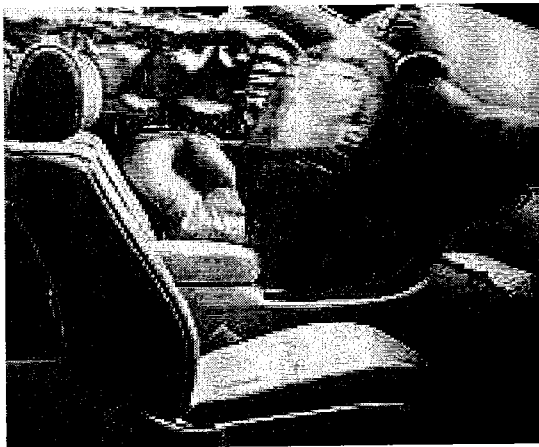
- ◆ Electric motors must be kept clean to allow for proper ventilation of internal components and related circuitry.
- ◆ Shrouds must be securely fastened to prevent vibration and the introduction of particles into the airstream.
- ◆ Foot mounts or skids must be in place to ensure the fan operates without unnecessary vibration.
- ◆ Fuel tanks must be kept full to ensure uninterrupted operations during incidents.
- ◆ Oil levels must be maintained within an acceptable range in order to limit wear and tear on engine components. Many modern motors will shut down or not start if there is not sufficient oil in the motor.
- ◆ Fan blades/propellers must be free of dents, nicks, cracks, or other defects.  
Warning: Damaged blades could fail during operation and lead to serious firefighter injuries or death!
- ◆ The fan blade/propeller must be installed with the pitch in the correct direction. The blade/propeller should have an arrow or indicator to identify which side should face forward.

## Vehicle Safety

### Introduction

Airbags were first introduced in the early 1970's and since then, vehicles, as well as their safety features, have developed rapidly. Since model year 1998, all new cars have been required to have air bags on both driver and passenger sides (light trucks came under the rule in 1999). There are many safety features located within the vehicles found on the road today and many more advancements can be expected. However, while these "safety" features are great for protecting the passenger upon impact they can be very hazardous to rescuers, and possibly the passengers, while working to extricate the patients from the vehicle. The dangerous possibilities of airbags were demonstrated by the injuries sustained by two firefighters from Ohio during an extrication. Both rescuers were injured when the multiple airbags deployed during extrication, seriously injuring one of the rescuers.

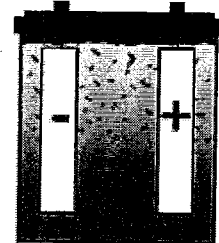
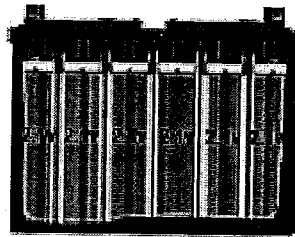
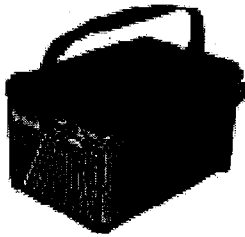
The following information is current as of late fall 2004. The automobile manufacturing industry has made great strides in the safety features of today's automobiles and will continue to make advancements in this field. All firefighter/rescuers must make every attempt to stay current with the technology of today and tomorrow.



### Batteries

Batteries used to be located under the hood either on the passenger side of the driver's side, however with modern day vehicles this is no longer the case. In today's vehicles batteries can be found under the hood, in the trunk, under the rear passenger seat, and just about anywhere else the manufacturer can find a place to put the battery.

Car batteries are lead-acid batteries. A car's battery is designed to provide a very large amount of current for a short period of time. This surge of current is needed to turn the engine over during starting. Once the engine starts, the alternator provides all the power that the car needs. A car battery may go through its entire life without ever being drained more than 20 percent of its total capacity. Used in this way, a car battery can last a number of years. To achieve a large amount of current, a car battery uses thin plates in order to increase its surface area.

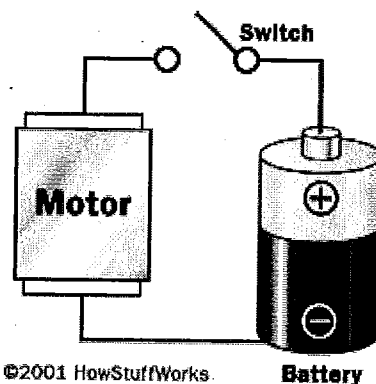


A car battery typically has two ratings:

- **CCA** (Cold Cranking Amps) - The number of amps that the battery can produce at 32 degrees F (0 degrees C) for 30 seconds
- **RC** (Reserve Capacity) - The number of minutes that the battery can deliver 25 amps while keeping its voltage above 10.5 volts

If you look at any battery, you'll notice that it has two terminals. One terminal is marked (+) or positive (usually red), while the other is marked (-) or negative (usually black). In an AA, C or D cell (normal flashlight batteries), the ends of the battery are the terminals. In a large car battery, there are two heavy lead posts that act as the terminals.

Electrons collect on the negative terminal of the battery. If you connect a wire between the negative and positive terminals, the electrons will flow from the negative to the positive terminal as fast as they can (and wear out the battery very quickly). This can be dangerous, especially with large batteries. Normally, some type of load would be connected to the battery using the wire. In automobiles the load is the motor.



Inside the battery itself, a chemical reaction produces the electrons. The speed of electron production by this chemical reaction (the battery's internal resistance) controls how many electrons can flow between the terminals. Electrons flow from the battery into a wire and **must**

**travel from the negative to the positive terminal** for the chemical reaction to take place. This is why a battery can sit on a shelf for a year and still have plenty of power. Unless electrons are flowing from the negative to the positive terminal, the chemical reaction does not take place. Once you connect a wire, the reaction starts.

## **Voltage**

In any battery, the same sort of electrochemical reaction occurs so that electrons move from one pole to the other. The actual metals and electrolytes used control the b of the battery -- each different reaction has a characteristic voltage. For example, here's what happens in one cell of a car's lead-acid battery:

- The cell has one plate made of lead and another plate made of lead dioxide, with a strong sulfuric acid electrolyte in which the plates are immersed.
- Lead combines with  $\text{SO}_4$  to create  $\text{PbSO}_4$  plus one electron.
- Lead dioxide, hydrogen ions and  $\text{SO}_4$  ions, plus electrons from the lead plate, create  $\text{PbSO}_4$  and water on the lead dioxide plate.
- As the battery discharges, both plates build up  $\text{PbSO}_4$  (lead sulfate), and water builds up in the acid. The characteristic voltage is about 2 volts per cell, so by combining six cells you get a 12-volt battery.

A lead-acid battery has a nice feature -- the reaction is completely reversible. If you apply current to the battery at the right voltage, lead and lead dioxide form again on the plates so you can reuse the battery over and over. In a zinc-carbon battery, there is no easy way to reverse the reaction because there is no easy way to get hydrogen gas back into the electrolyte.

## **Capacitors**

Capacitors were placed into vehicles to solve the problem of the vehicle battery being destroyed early in a crash and therefore no power was available to deploy the supplemental restraint systems. While these capacitors solved the problem of power loss they created a problem in that they can hold a back-up power supply for up to 30 minutes. This back-up power supply can lead to the deployment of the supplemental restraint systems during the patient extrication. The best way to attempt to prevent this is to disable the capacitor's power source -- the battery.

When disabling the battery the battery should be disconnected or cut on the negative side then the positive side. If disconnecting the cables, push them away from the terminal so that they will not go back into contact. If cutting the

cables it is best to cut them in two places therefore placing a gap in the wire so that they cannot reconnect.

Even after disconnecting the battery there is no guarantee that the airbags have been deactivated. As mentioned before the capacitor can hold a charge up to 30 minutes. The length of time each model of vehicle will hold a charge varies from 0 seconds to 30 minutes. Even after the capacitor has been discharged there are several factors that may allow for discharge of the airbags:

- Static electricity or delivering electrical power to the airbag system at any time
- Aftermarket accessories with battery back up power
- Vehicle and electrical fires
- Mechanical airbags (Volvo 850, 960 & 70 series side impact, front airbags 1993-1995 Cherokee, & pre 1996 Jaguar)
- Dual or multi stage airbags with live 2<sup>nd</sup> igniter
- Crushing or damaging the airbag computer module or SRS unit/DERM

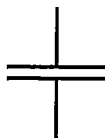
### How capacitors work

In a way, a capacitor is a little like a battery. Although they work in completely different ways, capacitors and batteries both store electrical energy. Inside the battery, chemical reactions produce electrons on one terminal and absorb electrons at the other terminal.

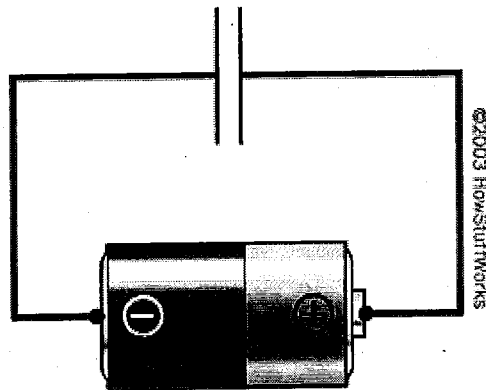
A capacitor is a much simpler device, and it cannot produce new electrons -- it only stores them.

Like a battery, a capacitor has two terminals. Inside the capacitor, the terminals connect to two metal plates separated by a dielectric. The dielectric can be air, paper, plastic or anything else that does not conduct electricity and keeps the plates from touching each other. You can easily make a capacitor from two pieces of aluminum foil and a piece of paper. It won't be a particularly good capacitor in terms of its storage capacity, but it will work.

In an electronic circuit, a capacitor is shown like this:



When you connect a capacitor to a battery, here's what happens:

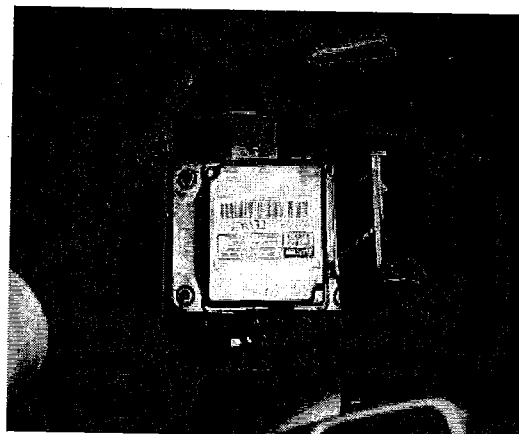
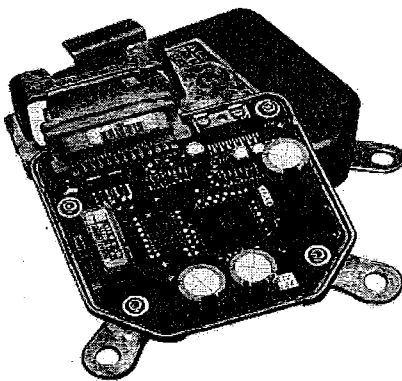
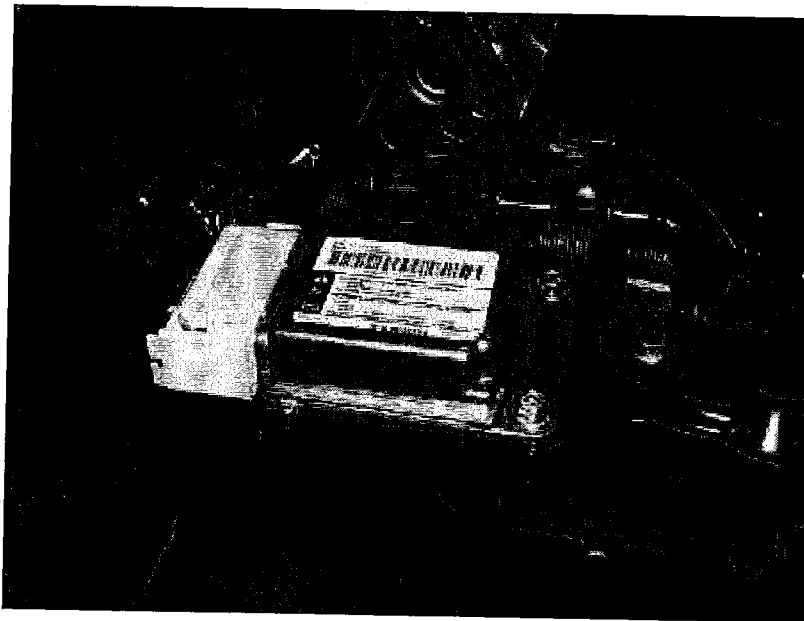


- The plate on the capacitor that attaches to the negative terminal of the battery accepts electrons that the battery is producing.
- The plate on the capacitor that attaches to the positive terminal of the battery loses electrons to the battery.

Once it's charged, the capacitor has the same voltage as the battery (1.5 volts on the battery means 1.5 volts on the capacitor). For a small capacitor, the capacity is small. But large capacitors can hold quite a bit of charge (think METRO). You can find capacitors as big as soda cans, for example, that hold enough charge to light a flashlight bulb for a minute or more. When you see lightning in the sky, what you are seeing is a huge capacitor where one plate is the cloud and the other plate is the ground, and the lightning is the charge releasing between these two "plates." Obviously, in a capacitor that large, you can hold a huge amount of charge!

## Control Module

The control module is where the capacitor is typically housed and will frequently have a master sensor for the supplemental restraint system (this may be the only sensor in the vehicle). The control module is also known as the Diagnostic Energy Reserve Module (DERM), Central Processing Unit (CPU), Electronic Control Unit (ECU), the computer or the "Brain." The control module may be found in several locations; under the center console, in the dashboard, in the passenger footwell area, etc.



GM 'black box' SDM air bag module. Mounted under center console. 2001 Cadillac DTS shown.

In addition to housing the capacitor this "black box" records the following information:

- Vehicle speed (in five one-second intervals preceding impact)
- Engine speed (in five one-second intervals preceding impact)
- Brake status (in five one-second intervals preceding impact)
- Throttle position (in five one-second intervals preceding impact)
- Driver's seat belt state (On/Off)
- Passenger's airbag enabled or disabled state (On/Off)
- Airbag Warning Lamp status (On/Off)
- Time from vehicle impact to airbag deployment
- Maximum Delta-V ( DV ) for near-deployment event
- Delta-V ( DV ) vs. time for frontal airbag deployment event
- Time from vehicle impact to time of maximum Delta-V ( DV )
- Time between near-deploy and deploy event (if within 5 seconds)

### **Sensors**

Sensors are used to send a signal to the control module in a crash. Some vehicles have a single sensor located in the control module while other vehicles have a number of sensors located throughout the vehicle.

The sensor is the device that tells the bag to inflate. Inflation happens when there is a collision force equal to running into a brick wall at 10 to 15 miles per hour (16 to 24 km per hour). A mechanical switch is flipped when there is a mass shift that closes an electrical contact, telling the sensors that a crash has occurred. The sensors receive information from an accelerometer built into a microchip.

### **Front Airbags**

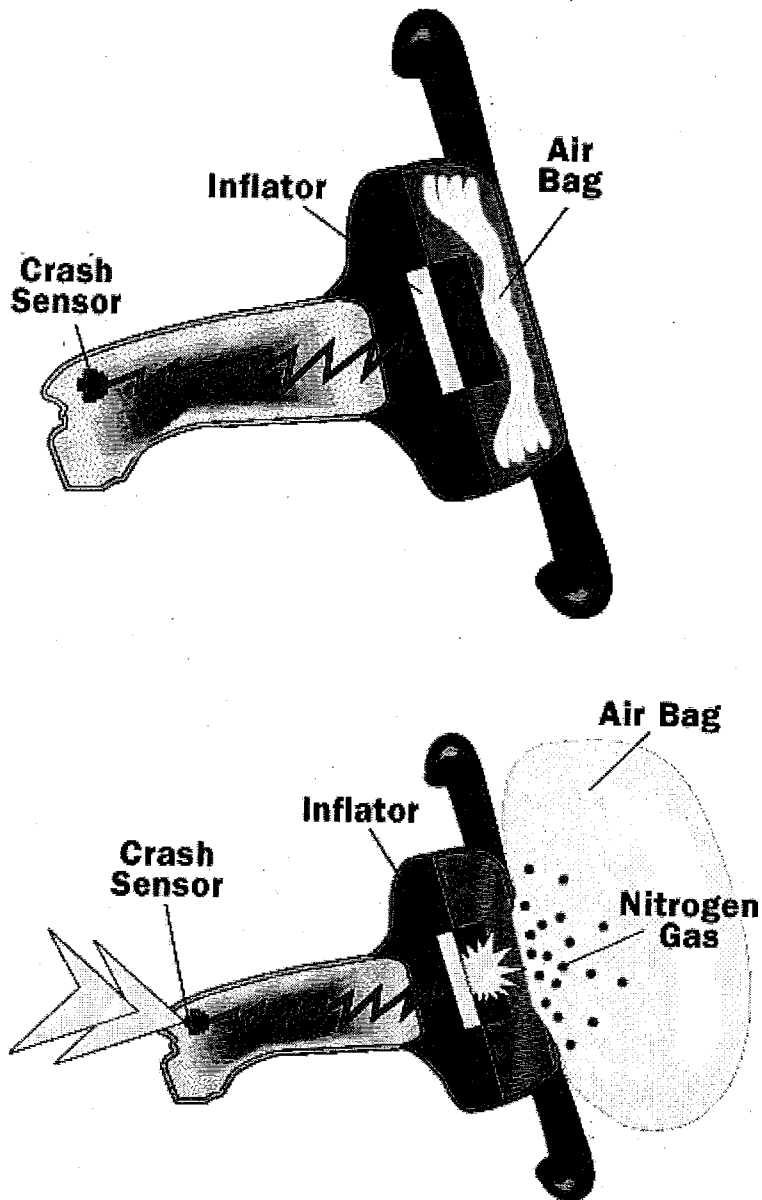
What an air bag wants to do is to slow the passenger's speed to zero with little or no damage. The constraints that it has to work within are huge. The air bag has the space between the passenger and the steering wheel or dash board and a fraction of a second to work with. Even that tiny amount of space and time is valuable, however, if the system can slow the passenger evenly rather than forcing an abrupt halt to his or her motion.

There are three parts to an air bag that help to accomplish this feat:

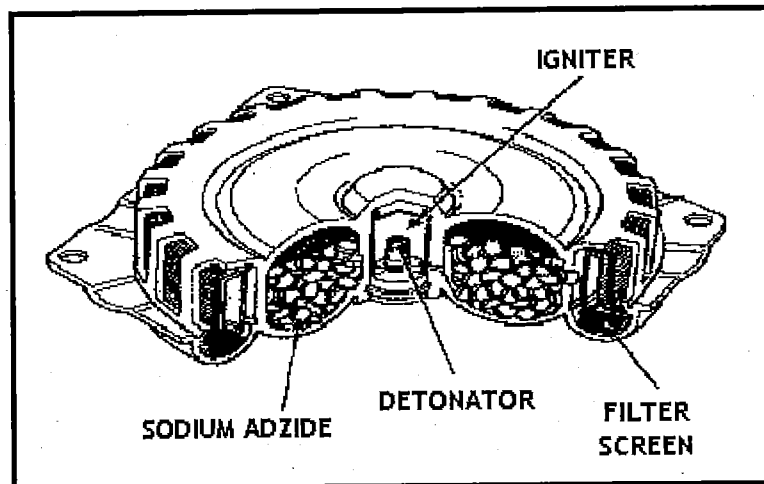
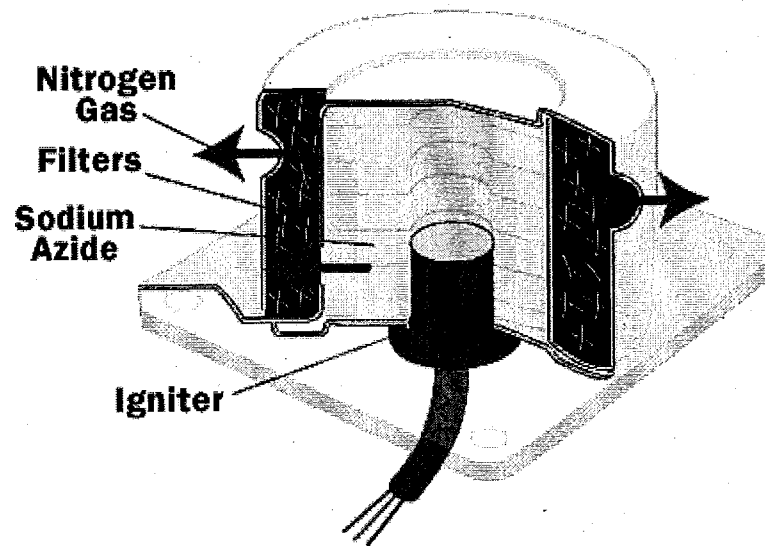
- The bag itself is made of a thin, nylon fabric, which is folded into the steering wheel or dashboard
- The sensor

- The air bag's inflation system reacts sodium azide ( $\text{NaN}_3$ ) with potassium nitrate ( $\text{KNO}_3$ ) to produce nitrogen gas. Hot blasts of the nitrogen inflate the air bag.

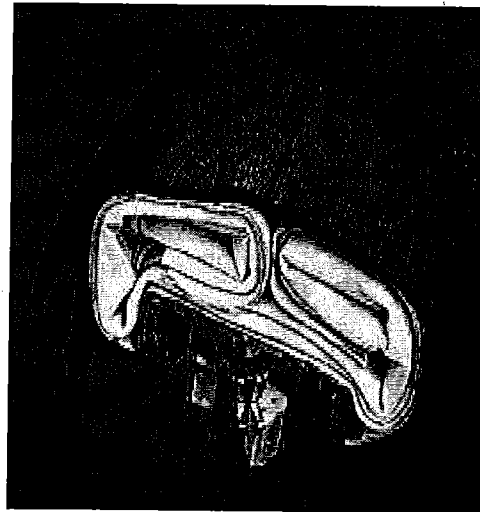
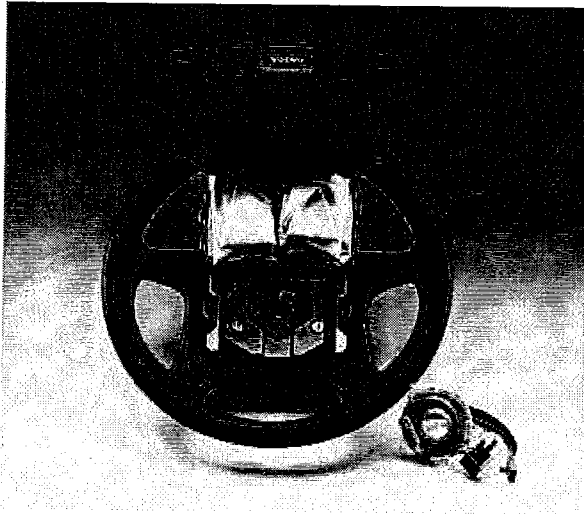
The inflation system is not unlike a solid rocket. The air bag system ignites a solid propellant, which burns extremely rapidly to create a large volume of gas to inflate the bag. The bag then literally bursts from its storage site at up to 200 mph (322 kph) -- faster than the blink of an eye! A second later, the gas quickly dissipates through tiny holes in the bag, thus deflating the bag so you can move. The latest generation of frontal airbags deploy with 20-to-35 percent less force than earlier versions.



## Air Bag Inflation Device

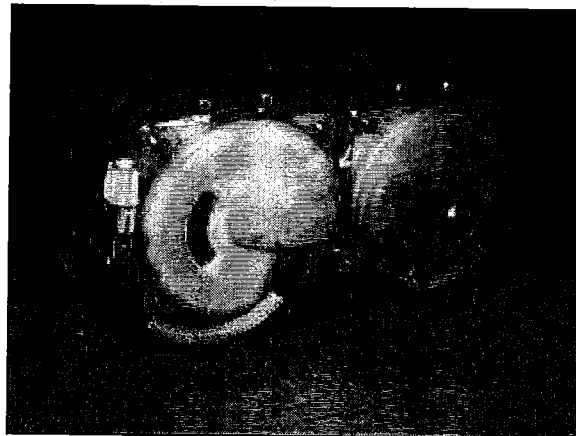


This is a diagram of a typical inflator assembly behind the steering wheel.



Even though the whole process happens in only one-twenty-fifth of a second, the additional time is enough to help prevent serious injury. The powdery substance released from the air bag, by the way, is regular cornstarch or talcum powder, which is used by the air bag manufacturers to keep the bags pliable and lubricated while they're in storage.

**AT NO TIME SHOULD ANY POST MANUFACTURED DEVICE BE PLACED OVER ANY AIRBAG.**

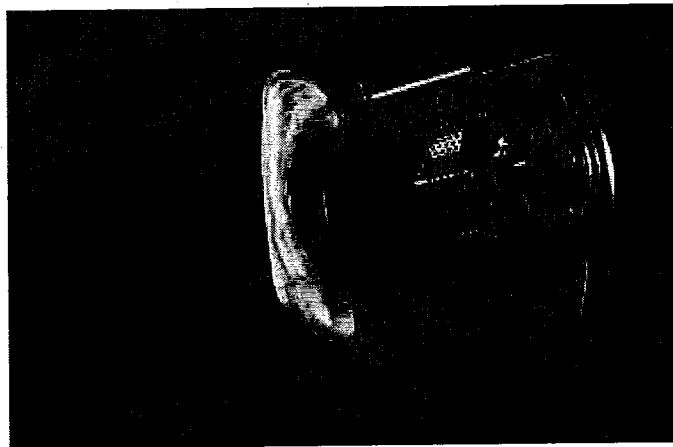


A view of the rear of this frontal airbag clearly shows the two separate inflator modules. This airbag is designed to fire only one inflator in a low-speed collision, leaving responders faced with a "dead" airbag with a "live" charge remaining.

## Passenger Side Airbag

In September of 1997, a mandate was issued for vehicle manufacturers to provide a front impact air bag for the passenger side of the vehicle. Several manufacturers had already introduced this passenger protection system beginning in 1990. By 1995 passenger side airbags were a common vehicle addition.

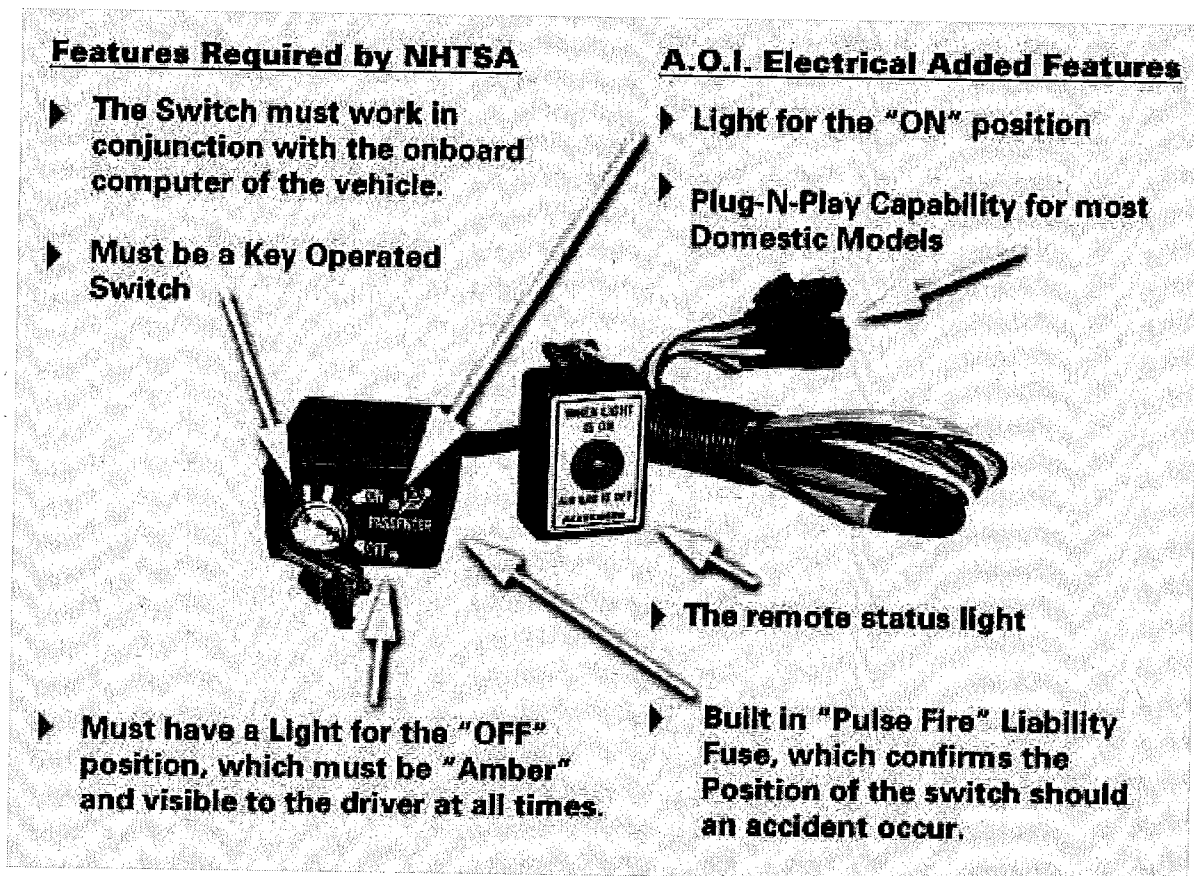
The passenger bag is mounted in the top of the dash on the passenger side of the vehicle. Below is a Photographic cross section of a Passenger Side Airbag Module



Some vehicles are equipped with an airbag switch allowing them to deactivate the passenger airbag. If during an extrication a vehicle is found to be equipped with this switch an attempt should be made to switch it to "off." While this does not guarantee that the bag will not deploy it is an extra step that should be taken to protect the patient, your crew, and yourself.



While some vehicles are manufactured with a switch as pictured above, other vehicles may contain after market switches pictured below.



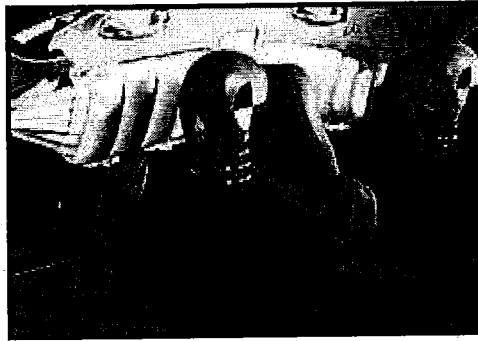
### Side Airbags

Side impact bags were first introduced by Volvo in 1995 and have rapidly increased in popularity. At the same time side impact airbags have had a lot of bad publicity because of multiple injuries and deaths related to side impact airbags. There are several different types of side impact airbags, included are:

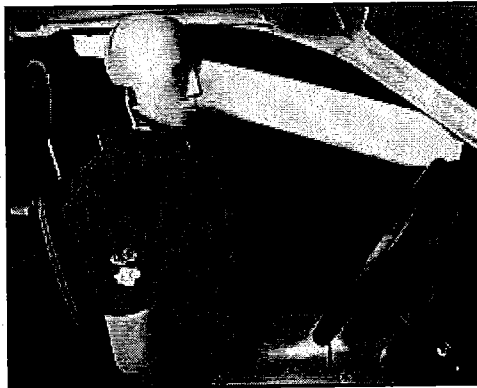
**The Head-Thorax Bag**



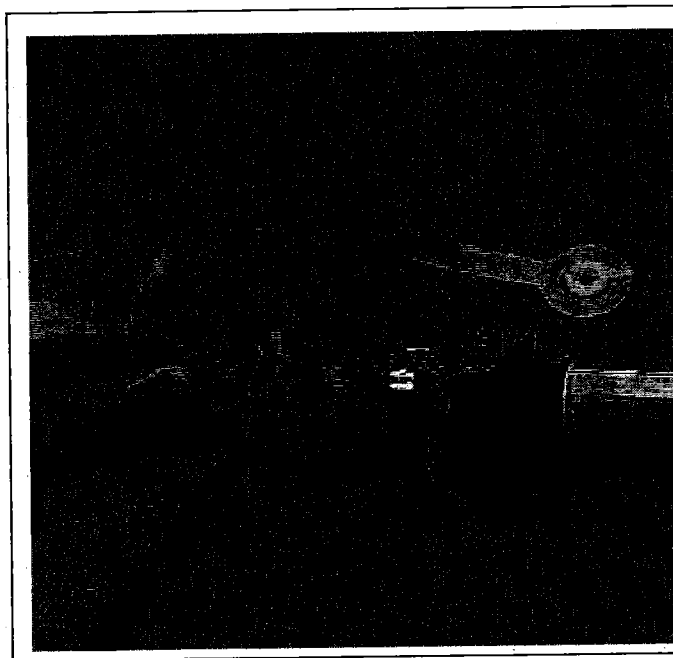
**Inflatable Curtain**



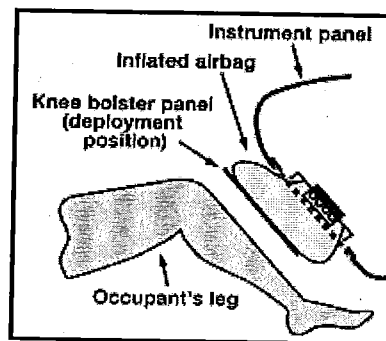
**Inflatable Tubular  
Structure**



**USE EXTREME CAUTION WHEN CUTTING THE C POST OF A VEHICLE  
WITH CURTAIN AIRBAGS! CUTTING THE FIRING MECHANISM MAY  
CAUSE UNDEPLOYED CURTAIN BAGS TO DEPLOY.**



## Leg Protection Bags



Autoliv has developed a new airbag in cooperation with Renault. The Anti-Sliding-Bag is installed in the front edge of the seat cushion to reduce the risk of the occupant sliding under the seat belt in a crash.

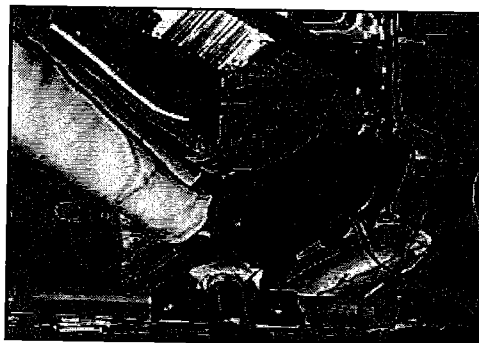


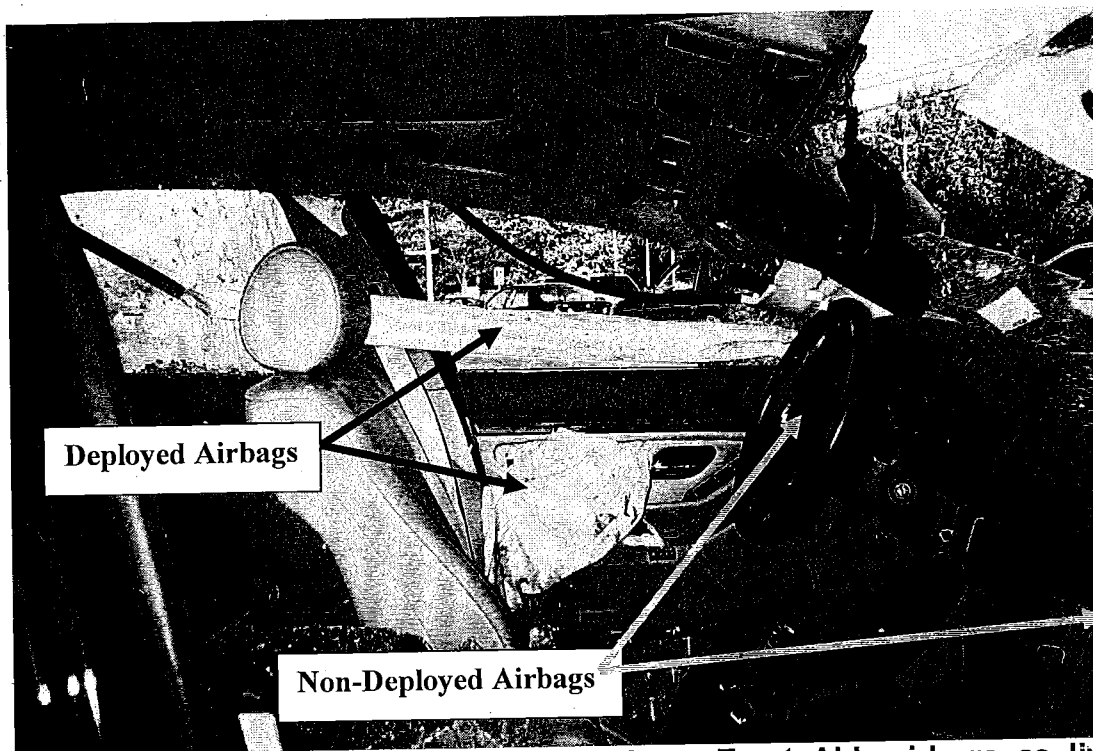
Without the Anti-Sliding-Bag



With the Anti-Sliding-Bag

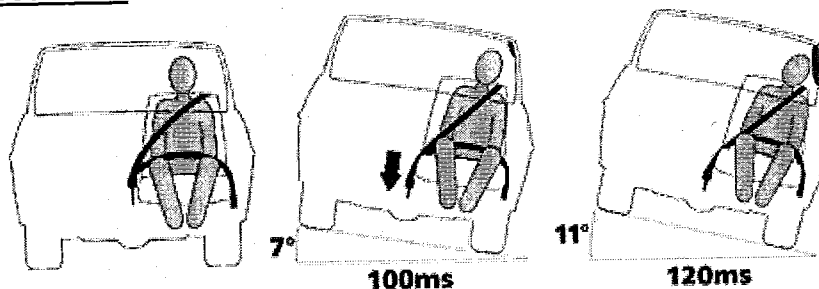
**Inflatable Carpet (InCa)** is a new protection system under development which will protect the car occupant's feet, ankles and lower legs in frontal crashes by removing the feet from the intruding foot well of the vehicle.





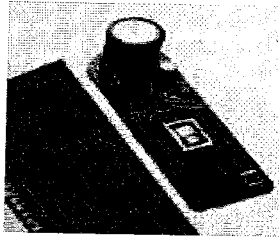
**Be Aware, not all airbags deploy together. Treat ALL airbags as live airbags!**

### **Rollover Protection**

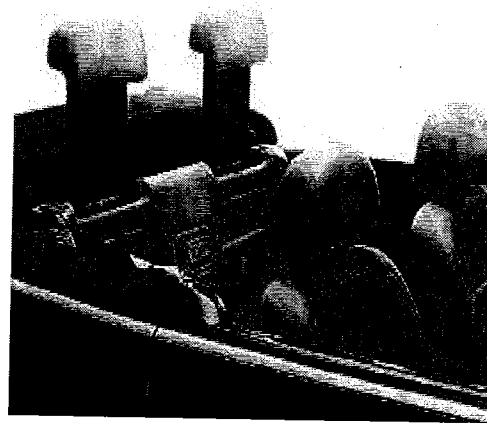
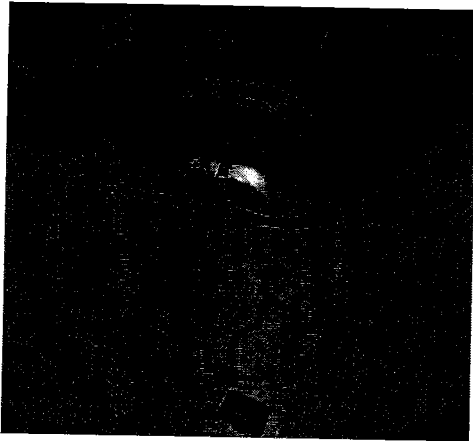


To maintain the clearance between the occupant's head and the roof of the vehicle, the vehicle can be equipped with a Belt-in-Seat system where the shoulder belt is attached to the backrest of the seat instead of to the pillar between the doors. The rollover also uses a new and very advanced micro-processed sensor which will trigger the seat belt pretensioners (to further increase the clearance between the roof and the occupant's head) and the Inflatable Curtains to help prevent the occupant's head from hitting that side of the vehicle or the ground. The Inflatable Curtain will also help prevent occupants from being ejected from the vehicle, which is very common in rollovers, especially among unbelted occupants.

### Micro processed sensor



A roll-over protection system, fitted as standard, which extends to a height of 265 millimeters within 0.25 seconds if a sensor detects an impending rollover or crash.



### Pretensioners

Pretensioners are incorporated into the belt assemblies to remove slack from the seat belt during a collision. Within milliseconds of a crash, the pretensioner is activated and increases the tension of the seat belt system around the occupant. This is what keeps you from bouncing around and keeps you in the proper position to benefit from the airbag if the crash is severe enough to trigger them. It contains an inertial reel with a pendulum device that senses sudden deceleration and automatically locks the belt in a crash. Currently there are three types of pretensioners in use today.

### **Mechanical**

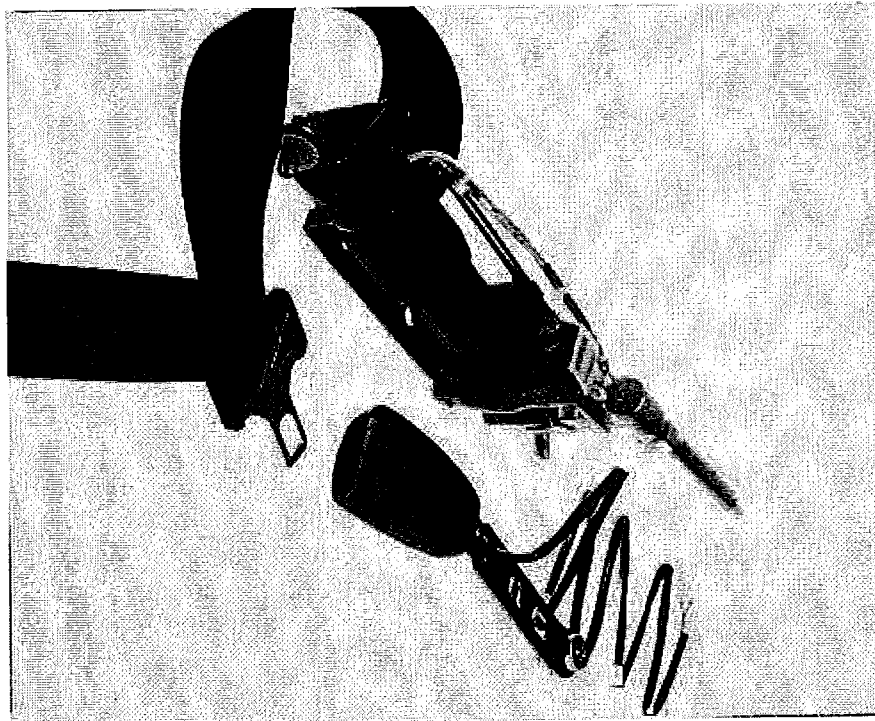
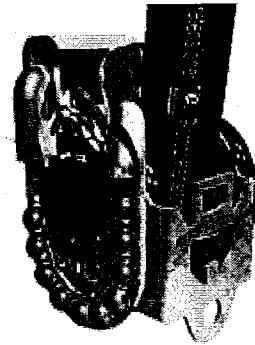
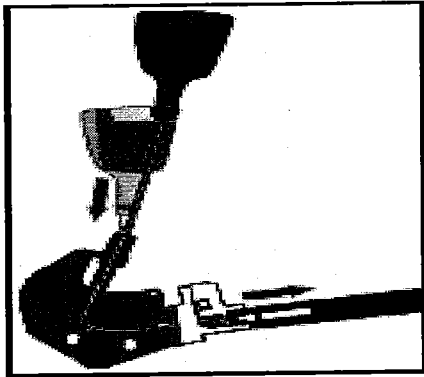
Mechanical pretensioners use an inertial wheel with a pendulum device that moves under the rapid deceleration of the crash to lock the belt into place. Such mechanisms can often be detected by giving a sudden tug on the belt. A mechanical pretensioner will automatically lock the belt into place, with the intent of limiting occupant travel in the event of a crash.

## Electrical

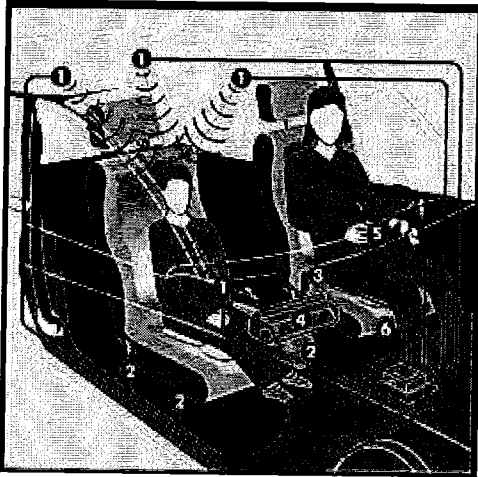
Electrical pretensioners replace the mechanical means of sensing deceleration (the pendulum) with an electrical device that may or may not be tied into the airbag ignition circuits.

## Pyrotechnic

Pyrotechnic pretensioners use electrically triggered pyrotechnics that tighten the seatbelt a prescribed amount upon sensing a crash event. These devices can operate on either the buckle or ratchet side of the seatbelt mechanism. These are the most highly technical type of pretensioner, and also the most expensive. These will be the focus of this report.



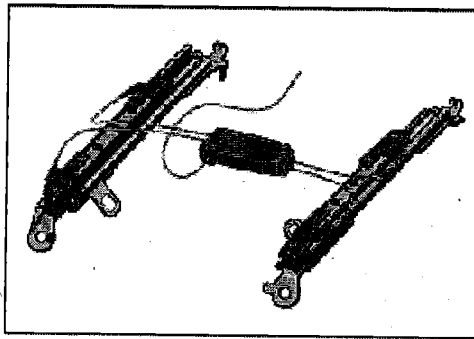
## Smart Systems



1. Ultra-sonic sensors
2. Weight sensors
3. Buckle sensors
4. Adaptive inflators
5. Hand Placement sensor
6. Seat position sensors

The Smart Airbag of the future is not just the airbag, but a redesign of the components in the current airbag systems. Features include:

- **Weight Sensors** This is a new sensor for the passenger seat to classify the weight and to determine what type of occupant is in the seat (adult or child).



- **Infrared Occupant Detection** This system will use Infra-red beams (just like in your TV remote control) to detect the distance the passenger is from the airbag and adapt the force of deployment accordingly.
- **Capacitive Reflective Occupant Sensing** These sensors will be located in the seat backs and in the dash to identify the distance you and or your passengers are from the dashboard. These sensors will be able to discriminate between a human occupant and inanimate objects like your groceries. This alone will save thousands of dollars in the cases where the driver is the only occupant in the front seat.

- **Updated SENSORS** The updated SENSORS will have the capabilities of deploying the seatbelt pretensioners faster, so in a crash situation you will be in the best position to benefit from the airbag deployment.
- **Centralized Electronic Control Unit** The new control units will be able use all the input from the new sensor technology and thru new software deploy what you need when you need it.

In addition, so-called "smart" frontal airbags on some vehicles are able to deploy at different degrees of force, depending on the severity of the crash and the weight of the occupant. Some vehicles come with suppression systems that prevent airbags from deploying if sensors detect a child in the front passenger seat. Such airbags will be required in all vehicles on a phased-in basis, beginning in 2004.

### **New Vehicle Construction**

Today's cars and trucks are specifically designed and built to help passengers survive a wide range of types and severities of collisions. So-called "crumple zones" at the front and rear of a vehicle are engineered to absorb and redirect crash forces. Hoods are engineered to collapse so they won't be forced through the windshield. Doors are designed to remain intact and overlap upon impact so passengers will be able to exit the vehicle. Doors are also equipped with more-secure hinges and latches so they won't spring open to eject passengers. Heavier firewalls and specially designed engine mounts help send components down and under the passenger area, so they won't come crashing into the front seat. Windshields are specially laminated to help prevent not only injuries from shattering glass, but ejection from the vehicle in a collision.

Stronger passenger compartments, reinforced by race-carlike "safety cage" structures offer cocoonlike protection to help keep the occupant area intact in an accident. Padded, energy-absorbing materials and other interior design elements further help reduce injuries. Head restraints, now being added to rear as well as front seats, help prevent whiplash injuries. Some automakers, including Volvo, Saab, and General Motors, have introduced head restraints that move slightly under certain crash conditions to help further reduce neck injuries. Still, all else being equal, the laws of physics dictate that a larger and heavier car will provide its passengers with better protection in a crash than would a smaller and lighter vehicle.

The massive developments in the area of vehicle safety construction have meant that both extrication techniques and equipment have had to change in order to keep up with the advances in the automotive industry. It is critical for rescuers to keep up to date on the advances in vehicle safety systems and construction as well as the advances by the manufacturers of extrication equipment. Only with a strong working knowledge of these components as well

as many hours of hands-on training and experience will a rescuer be able to perform competent and efficient extrication.

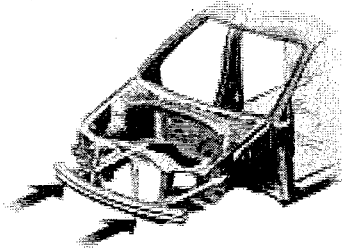
A great place to keep up on the advances in new car construction and safety systems is automotive manufacturer's web sites, the mechanics at area new car sales offices, and yearly auto shows. The information you learn at these locations could help save the life of a patient or even your own. The following are some of the changes that have occurred in new model vehicles, however, between the time of this being written and you reading this there have probably been additional improvements and modifications.

- Increased amount and types of metals used in posts as well as the number of bends
- Boron rod reinforced dashboard area
- Reinforced wheel and engine deflection systems that deflect the wheels and motor under the car and away from the passenger compartment area
- Crumple zones that absorb the energy of the impact (more damage, less injuries)
- Micro alloys and boron steel being used to improve the strength to weight ratio
- High Strength Low-Alloy or Ultra High Strength Low-Alloy steel being used to reinforce roof and pillar structures
- Side and rear glass – may have two panes of tempered glass, be laminated glass, bulletproof glass, or lexan
- Body materials consists of high impact plastic, carbon fiber, aluminum and other composite materials. These changes lead to more crumpling and shattering of material rather than bending. At times it may be easier to remove exterior panels to access purchase points. Carbon fiber is very difficult to cut/shatter and its dust particles and combustion by-products are hazardous

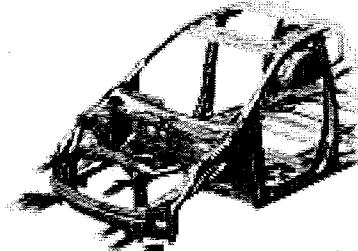


This picture demonstrates double panes of tempered glass.

### Advanced Compatibility Engineering (ACE) Body Structure

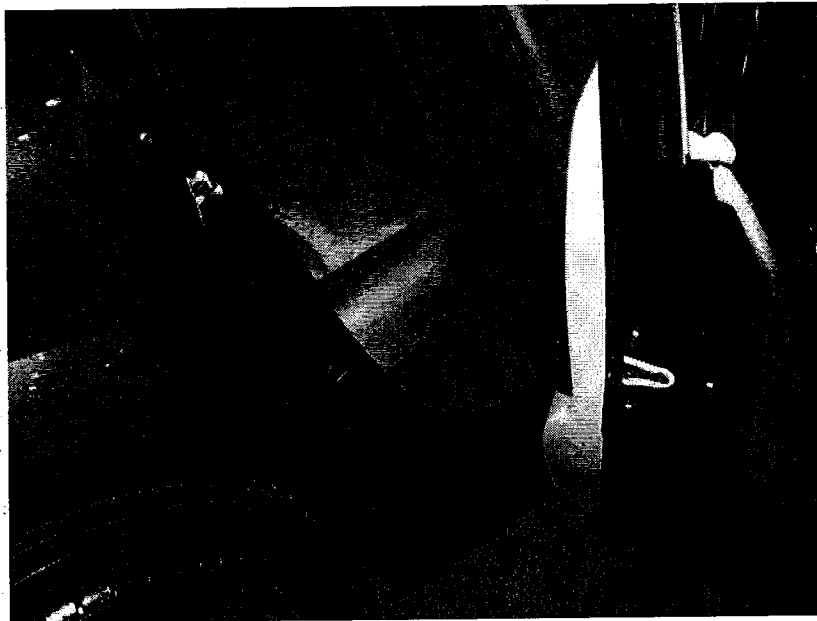


Previous Odyssey Minivan

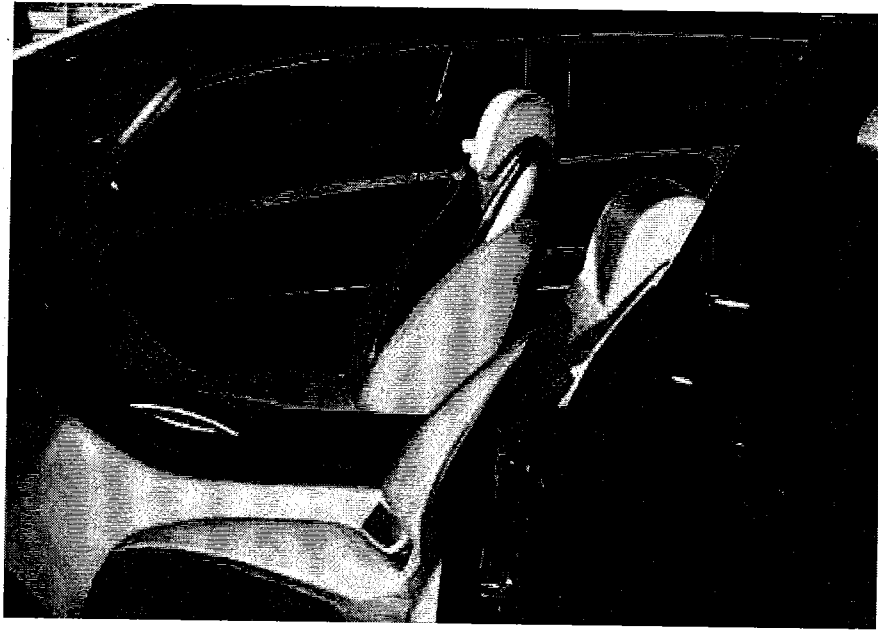


New 2005 Odyssey with ACE body structure

The above picture shows the improvements in passenger safety through stronger materials that absorb the impact.

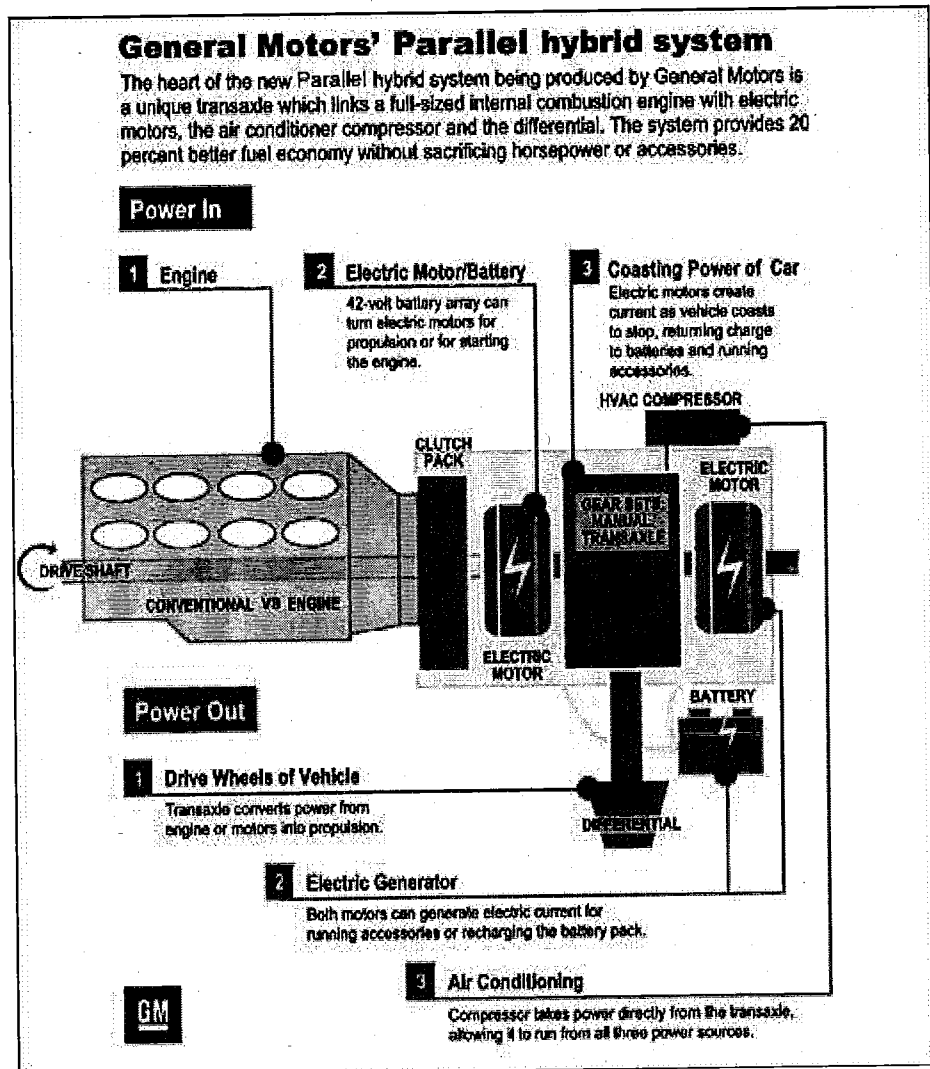


The above picture shows high impact plastic exterior panels as well as a deep door that will hamper rescuers accessing the U bolt.

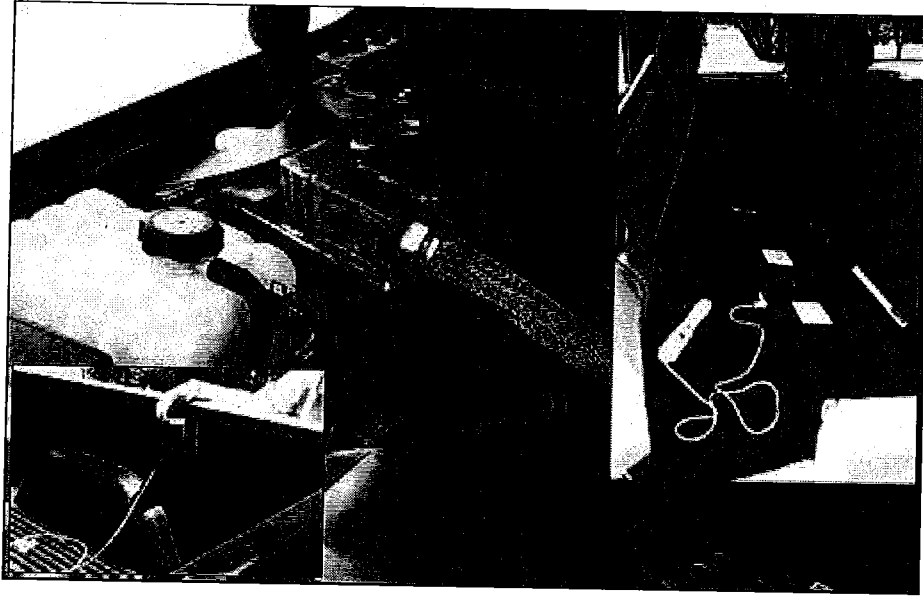


The above picture shows new car construction that has eliminated the upper portion of the "B" post.

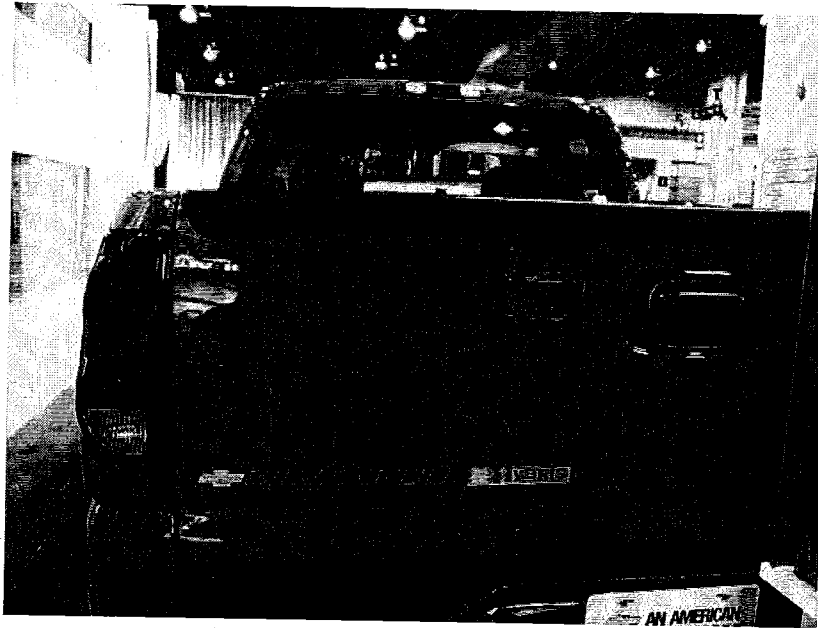
## Alternate Powered Vehicles



Displacement on Demand uses the oil pump system for hydraulic pressure to activate the system. Four control valve solenoids then act together to achieve seamless transition between four and eight cylinder operation.

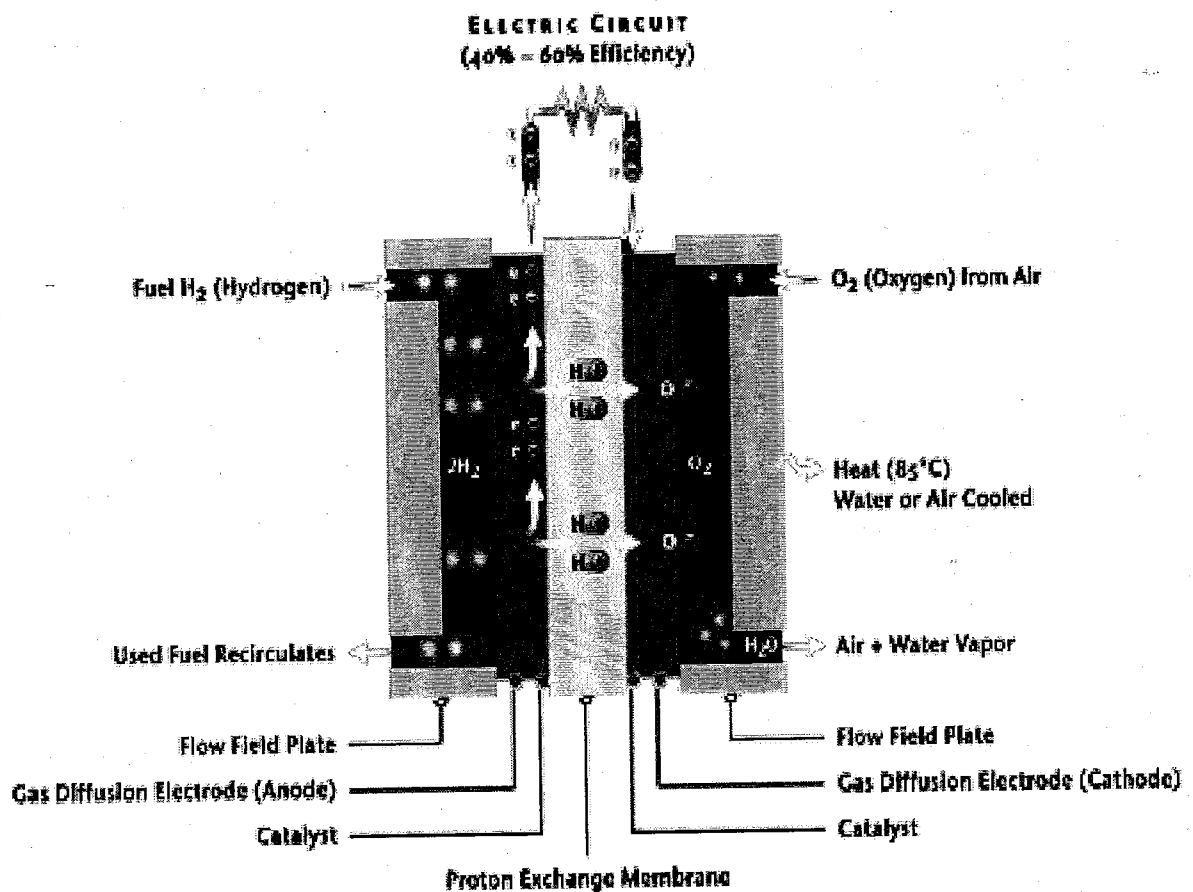


Three large lead-acid batteries are positioned under the rear seat to store power.

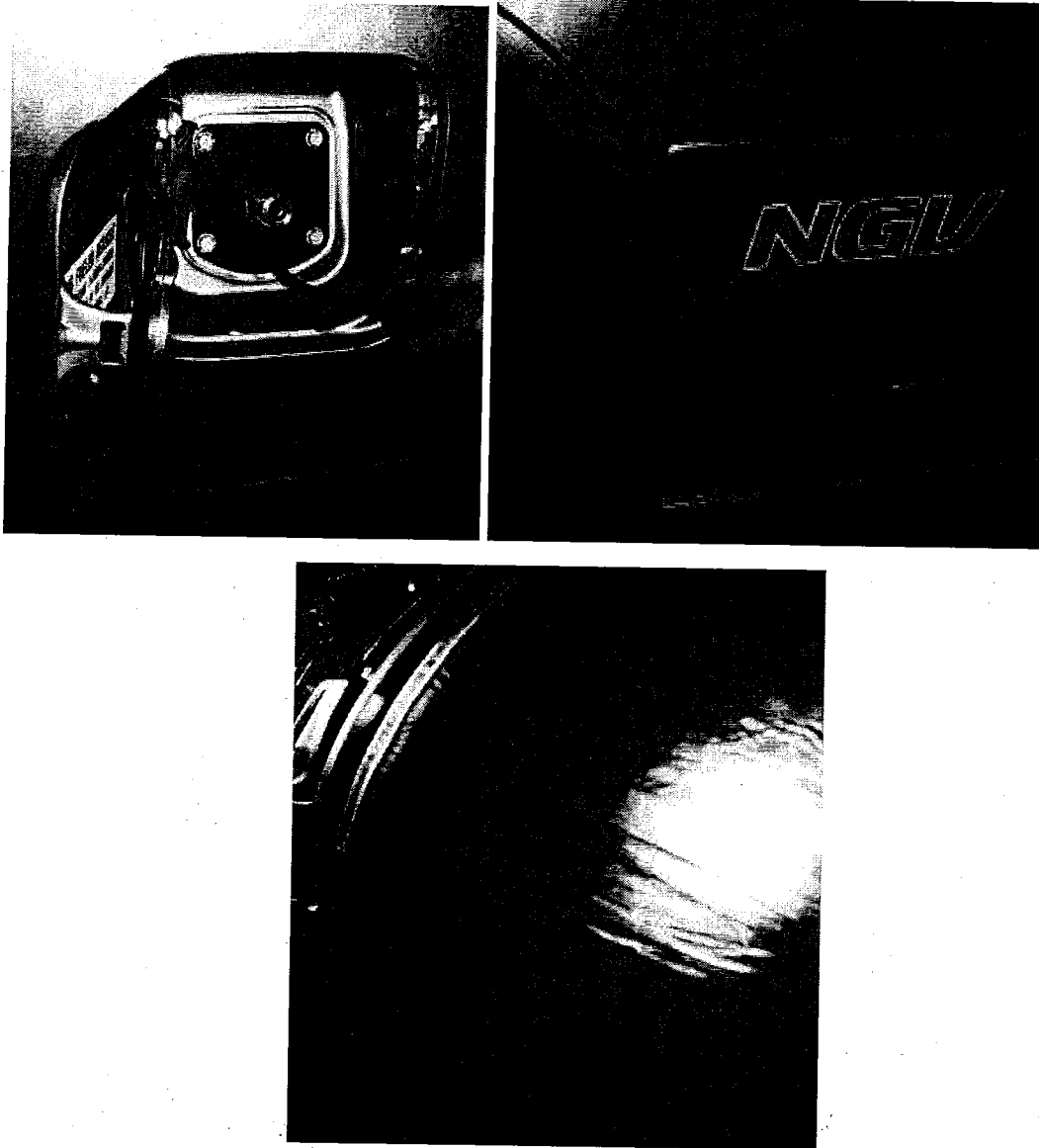


## Electric Power from Hydrogen Fuel

1. Fuel cells create electricity through an electrochemical process that combines hydrogen and oxygen.
2. Hydrogen fuel is fed into the anode of the fuel cell. Helped by a catalyst, hydrogen atoms are split into electrons and protons.
3. Electrons are channeled through a circuit to produce electricity.
4. Protons pass through the polymer electrolyte membrane.
5. Oxygen (from the air) enters the cathode and combines with the electrons and protons to form water. Water vapor and heat are released as byproducts of this reaction.




## Natural Gas Vehicle



Above is a picture of the tank that holds the compressed natural gas. This tank is located between the rear passenger seat and the trunk and can be accessed easily from the trunk.


**C.A.F.S. On-Line Orientation**  
 Manufacturer's Company  
 Fire & Rescue Service



*Classroom Training Module*

HALE  
 CHARTER

**Classroom Training Module**



HALE  
 CHARTER

**Classroom Training Module**

- Manufacturer's Company
- Fire & Rescue Service
- Fire & Rescue Service
- Fire & Rescue Service
- Fire & Rescue Service
- Fire & Rescue Service
- Fire & Rescue Service

HALE  
 CHARTER

**Classroom Training Module**

Manufacturer's Company  
 (As Purchased From The Manufacturer)

**Foam Solution**  
 Air & Mechanical Agitation  
**Finished Foam**  
 (Air Aspirated Foam Solution)

HALE  
 CHARTER



- 

三、前代の文法書に於ける「カ」の用法



## How do I Make CAFS?

There are a variety of ways to power the components, but all CAFS systems have three basic systems, which must work together.

## CAFS Triangle

These are the components that work together to make CAFS.

Air Compressor



Foaming Pump

Water/Water

## Advantages of CAFS

- o Increased penetration (high energy)
- o Increased "soaking" ability
- o Clings to vertical surfaces
- o Lighter hose lines

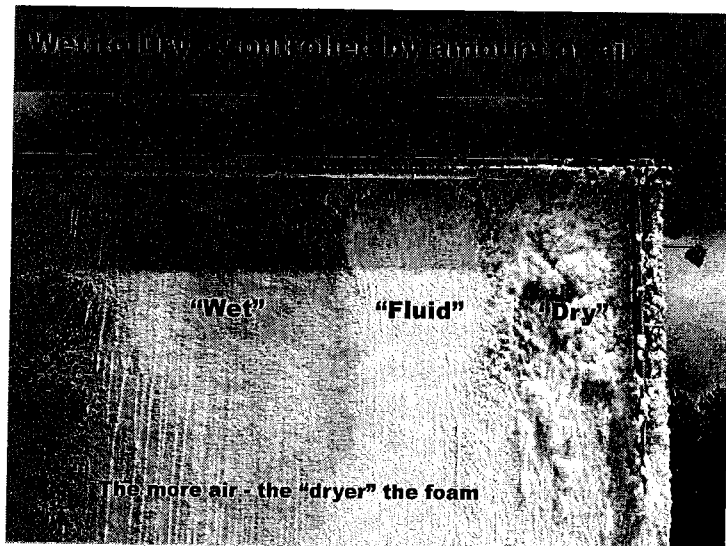
*More efficiently use water*

## Wet vs. Dry

- o Prefers to proportion air to water

The more air the drier it is.  
Can also be affected by "richness" of foam mixture.

If you add more foam concentrate, the (thinner) foam will be drier. As full dryness, the foam concentrate proportion automatically gets kicked up to 1%.



## Review Questions

List what the following ingredients of Class A Foam do and explain why they help to put out Class A fires.

- Surfactants
- Emulsifiers
- Foaming Agents

- List the three parts of the CAF's triangle.
- List the components of finished foam.
- How does CAF differ from NFAP?



### Materials and Methods

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

Spring 1999

Resolving Conflicts of Interest: Panel 10/11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 8

24. The two colliding oscillators are pendulums, each of

## How does an AFF-ATC work?

### Shortest Hydrophobicities

- Shortest hydrophobicities are the most abundant and in the most abundant black to white color.
- The shortest hydrophobicities are the most abundant and in the most abundant black to white color.
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## Clonidine (Naloxone) Universal Gold (1% x 3%)

When combined with Naloxone, Clonidine will be used as a 1% x 3%.

- 1% x 3% combination of Clonidine and Naloxone will be used as a 1% x 3%.
- 1% x 3% combination of Clonidine and Naloxone will be used as a 1% x 3%.



## FoamMidget Class B Foam Proportioning System

When proportioning system is to be installed, which can be done in place or in the shop.

When installed:

Proportioning system is installed in the pump system.

Proportioning system is installed in the pump system.



## FoamMidget Around the Pump

Proportioning system is installed in the pump system.

When installed, which can be done in place or in the shop.

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## FoamMidget Operation

Proportioning system is installed in the pump system.

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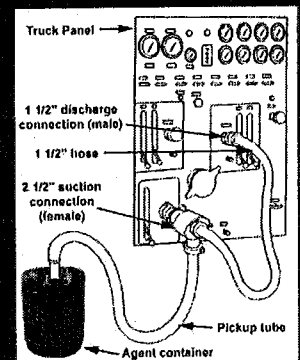
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## 95 GPM In-Line Extractor

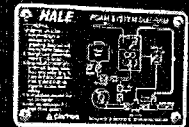
### Product Features

- 100% stainless steel construction for long life and resistance to corrosion
- 100% stainless steel construction for long life and resistance to corrosion
- 100% stainless steel construction for long life and resistance to corrosion
- 100% stainless steel construction for long life and resistance to corrosion
- 100% stainless steel construction for long life and resistance to corrosion



## 95 GPM In-Line Extractor

95 GPM In-Line Extractor. This unit is designed for use in a variety of applications. It is a 100% stainless steel unit with a 100% stainless steel construction. It is a 100% stainless steel unit with a 100% stainless steel construction. It is a 100% stainless steel unit with a 100% stainless steel construction.



100% SS

95 GPM In-Line Extractor. This unit is designed for use in a variety of applications. It is a 100% stainless steel unit with a 100% stainless steel construction. It is a 100% stainless steel unit with a 100% stainless steel construction. It is a 100% stainless steel unit with a 100% stainless steel construction.

## Nozzle Assisted Spray System (NASS)

### Product Features

- 100% stainless steel construction for long life and resistance to corrosion
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### Product Features

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## Corrosion Resistant Class 13 N/A 130 capabilities

### Product Features

- 100% stainless steel construction for long life and resistance to corrosion
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## Review Questions

- What is the proper proportioning rate for Chemtreat Universal Guard for use on an 1 1/2" grooved line? If you use 3000 gallons of foam solution to put this above fire out, how many gallons of foam concentrate did you use?
- Explain how to use the 95' grooved line reducer.

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## Final Thoughts - Safety Check!

- Pump Operations
- Foam Compatibility
- Attack Phase Compatibility
- Proper Hose Handling Techniques
- Foam Type Utilization
- Proper Bleeding, Breakdown and Take-Up Practices

CONSIDER THE FACTS AND ASSUME THE RESPONSIBILITY!

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- LTC Steven J. Johnson, President, Hale Products, Inc.
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